The Relationship Between Innovation Capabilities, Information Management, and HIT Quality in Healthcare Organizations:
Development of a Sociotechnical Model

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Preface

After graduating from high school in 2008, I served my civilian service as a patient transporter and nursing assistant in a large urban teaching hospital, which was my first in-depth introduction to hospital care. The job made me a first-hand witness to the blatant inefficiencies in care processes borne out of the use of paper-based documentation and to startling instances of information loss caused by overly simplistic one-way pager systems. Patients were forgotten to be sent to diagnostic appointments or left stranded for hours in busy hallways, calls for urgently needed blood bags for polytrauma patients undergoing surgery went into the abyss, patient records got lost or were left lying around in the open for anybody to read, and unreadable hand-written lab and diagnostic orders led to errors and delays. As a consequence, I quickly developed an interest in how innovative health information technology (HIT) might help to clear process inefficiencies and safeguard the patient from being subjected to unpleasant and even harmful care practices. A subsequent internship in the same hospital assisting the project management team in implementing a new hospital information system qualified me to enter a study program on the management of healthcare organizations. During my studies, I was increasingly exposed to the emerging potential of innovative information technologies for hospital care and learned how other countries appeared to manage the digital transformation more successfully. Simultaneously, I developed a deep interest in making complex phenomena measurable in order to assess messy and multi-layered management problems as objectively as possible – counter to the anecdotally driven management teachings that frequently prevail in the field. This also drew me to the soberness, cleverness, and rigor that empirical research and statistical methods can introduce to attempts of understanding reality, culminating in the realization that research might be an ideal place for my combined interests. Fortunately, Prof. Dr. Ursula Hübner provided just the right environment and opportunity to conduct research on HIT and its management. She quickly directed my attention to questions on what factors specifically might facilitate HIT innovations in clinical care, thereby providing the foundations for developing this thesis.

I want to especially thank her as well as Prof. Dr. Birgit Babitsch for their unwavering support and for providing guidance as well as critical discussions on the premises, methods, structures, and contents of this thesis. I also want to thank all team members of the Health Informatics Research Group, who provided a superb environment for conducting the research and discussing and disseminating the results. A special thanks goes to Prof. Dr. Jan-David Liebe, who supported the research from start to finish with his creative impulses and critical reflections, as well as to Jens Hüsers, who reinforced my interest in research and statistics early on and was an excellent source for cross-validating the statistical approaches in light of the newest developments in the field. Furthermore, I want to thank Dr. Johannes Thye, Laura Naumann, Dr. Jan-Patrick Weiß, and Dr. Jens Rauch for the close collaborations, especially concerning the data collection and pre-processing, as well as Maria Hasselbach for her support in researching the numerous contact data needed to conduct the surveys. I also want to thank the CIOs and clinical directors who invested their valuable and scarce time to provide input in the workshops and the review of the various survey items (Katja Kümmel, Dr. Carsten Giehoff, Thorsten Kleemann, Lothar Witeczek, Stefan Smers, Martin Pope, Hardy Zießler, Iris Mayenburg-Altwarg, Edith Böggemann, Petra Koop & Ingo Mette) as well as Prof. Dr. Elske Ammenwerth, Prof. Dr. Alfred Winter and Franziska Jahn for their inputs to the development and refinement of the scale sets. Lastly, I would like to thank my family and especially my girlfriend Annika for their loving and understanding support.

Abstract

Background: Healthcare organizations are critical for translating health information technology (HIT) based innovation into clinical care support. Despite their importance, very few reliable accounts exist about organizational facilitators, not only for the adoption of HIT systems but also for the systems' quality (i.e., HIT quality). However, it can be assumed that an organizational climate that embraces innovation and reflects the ability to innovate, i.e., *organizational innovation capabilities*, together with *professional information management* practices, may act as essential facilitators of HIT quality. Yet, there is no coherent conceptualization and corresponding measurement frameworks of both organizational innovation capabilities as well as of professional information management and no evidence on how they affect HIT quality. Addressing this issue also requires taking external influences, such as the legal-financial environment, into account, as prior research has pointed to their integral role in promoting the uptake of HIT in healthcare organizations.

Objective: The primary aim of this thesis is twofold: First, to find out what constitutes both innovation capabilities and professional information management and to develop corresponding measurement models. Second, to research the relationship between innovation capabilities, the professionalism of information management, and indicators of HIT quality – specifically the HIT workflow support and its perceived quality – in light of different legal-financial environments.

Methods: Quantitative data from representatives of hospitals (CIOs and clinical directors) in Austria, Germany, and Switzerland were collected across four separate surveys and used to develop a sociotechnical model that interlinks all relevant constructs. The model development spans five publications. Throughout these publications, the central constructs were developed iteratively using factor analytic techniques and their interrelationships tested using various regression techniques. The final model was established by applying partial least squares structural equation modeling.

Results: Various insights on the constituents of organizational innovation capabilities and information management as well as on their association to HIT quality were yielded across the publications, culminating in the proposal of the so-called IQ_{HIT} model in the last publication. Most importantly, the results confirmed a strong link between the innovation capabilities on different organizational levels and HIT quality. Specifically, the top management team's and the IT department's innovation capabilities positively influenced the degree of HIT workflow support and the perceived HIT quality. This effect was entirely mediated by the professionalism of information management. Moreover, the legal-financial environment showed to affect both the organizations' innovation capabilities as well as several measures of HIT quality across publications.

Conclusions: The results should encourage executives and decision-makers to realize the significant impact their organizations can exert on the level of HIT quality and thus to take agency in shaping the digital transformation in healthcare. They may do so by aiming to facilitate an organizational climate that encourages innovation and by establishing professional information management activities. Nevertheless, further studies to validate and extend the findings are warranted and the IQ_{HIT} model provides various access points to do so.

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List of Abbreviations

ADT	Admission, Discharge, Transfer
AHP	Analytic Hierarchy Process
AT	Austria
AVE	Average Variance Extracted
CAF	Clinical Adoption Framework
CB-SEM	Covariance-Based Structural Equation Modeling
CDSS	Clinical Decision Support System
CEO	Chief Executive Officer
CFA	Confirmatory Factor Analysis
CFI	Comparative Fit Index
CFIR	Consolidated Framework for Implementation Research
CH	Switzerland
CIL	Clinical Information Logistics
CI	Confidence Interval
CIO	Chief Information Officer
CITA	Clinical IT-Agents
COBIT	Control Objectives for Information and Related Technology
CPOE	Computerized Provider Order Entry
CR	Composite Reliability
DRG	Diagnosis Related Group
DoI	Diffusion of Innovation
DWLS	Diagonally Weighted Least Squares
EEG	Electroencephalography
EFA	Exploratory Factor Analysis
EHR	Electronic Health Record
ELGA	Elektronische Gesundheitsakte
EMRAM	Electronic Medical Record Adoption Model
EPD	Elektronisches Patientendossier
FIMIX-PLS	Finite Mixture Partial Least Squares Segmentation
G-DRG	German Diagnosis Related Group
GER	Germany
GMDS	German Association for Medical Informatics, Biometry and Epidemiology
HIE	Health Information Exchange
HIMSS	Healthcare Information and Management Systems Society

HIT	Health Information Technology
HITECH	Health Information Technology for Economic and Clinical Health
HOT-Fit	Human, Organization, and Technology-Fit
HTMT	Heterotrait-Monotrait Ratio
IC	Innovation Capability
IC ITD	Innovation Capability of the IT Department
IC OW	Organization-Wide Innovation Capability
IC TMT	Innovation Capability: Top Management Team Support
ICU	Intensive Care Unit
IM	Information Management
IK	Institutionskennzeichen
IQ_{HIT}	Innovation and Quality of Health Information Technology
IS	Information System
ITIL	IT Infrastructure Library
KHZG	Krankenhauszukunftsgesetz
KMO	Kaiser-Meyer-Olkin criterion
LOS	Length of Stay
NASSS	Nonadoption, Abandonment, Scale-up, Spread, and Sustainability
NHS	National Health Service
NPT	Normalization Process Theory
OECD	Organisation for Economic Co-operation and Development
OGIP	Overall Goodness of Information Provision
OR	Odds Ratio
PACS	Picture Archiving and Communication Systems
PCA	Principal Component Analysis
PHITS	Perceived HIT Workflow Support
PIM	Professionalism of Information Management
PKMS	Pflegekomplexmaßnahmen-Score
PLS-SEM	Partial Least Squares Structural Equation Modeling
QRF-EHR	Quality Requirements Framework of EHRs
RBV	Resource-Based View
RMSEA	Root Mean Square Error of Approximation
SC	Structural Characteristics
SD	Standard Deviation
SEM	Structural Equation Modeling
SNIK	Semantic Network of Information Management in Hospitals
SRMR	Standardized Root Mean Squared Residual

STS	Sociotechnical Systems Theory
TLI	Tucker-Lewis Index
TMT	Top Management Team
TOE	Technology-Organization-Environment
ULS	Unweighted Least Squares
UV	Underlying Variable
VIF	Variance Inflation Factor
WCS	Workflow Composite Score

1. Introduction

Healthcare organizations are increasingly challenged by the ongoing developments in medical informatics and the opportunities created by innovation in health information technology (HIT). The ubiquitous use of modern HIT systems, coupled with advanced methods of data analysis, promises to enable a paradigm shift in medicine: From traditional one-treatment-fits-all approaches towards individualized precision medicine (Mirnezami et al. 2012), embedded in health systems that cultivate continuous learning cycles across organizational and sector boundaries (Friedman et al. 2015). Realizing these visions places high demands on healthcare organizations and can be crucial to their future success. As Toby Cosgrove, former president and chief executive officer of the Cleveland Clinic, stated, "*The future belongs to those who seize the opportunities created by innovation*" (Graham 2018). Unfortunately, however, most healthcare organizations struggle to do so. While the technological capabilities of HIT systems continue to grow, adoption rates even of basic technologies such as electronic medical record systems remain modest in many organizations (Esdar et al. 2019; Stephani et al. 2019). This leads some to contend that, while healthcare organizations should indeed aspire to be HIT innovators, most tend to instead classify as "HIT laggards" (Leidner et al. 2010). And even when organizations manage to reach higher adoption rates, many end up wrestling with various unintended consequences of HIT systems that are often misaligned with clinical workflow needs, such as increased clinician burnout (Gardner et al. 2019) or "innovation vacuums" concerning the further advancement of those systems (Colicchio et al. 2019).

There are significant differences in HIT adoption rates between developed countries (Ammenwerth et al. 2020) which might indicate that successful HIT use is simply a matter of having the right governmental policies in place. However, the gap between the expectations of HIT systems and their usage in practice cannot merely be assigned to a lack of political motivation and respective actions on a national level as almost all developed countries have made it a priority to digitize health care (World Health Organization 2016) and there is still substantial variation across organizations within countries (Martin et al. 2019; Sabes-Figuera and Maghiros 2013; Liebe et al. 2015). Rather, barriers and facilitators on the level of individual organizations seem to pose a critical bottleneck in implementing and innovating HIT systems in a way they actually support clinical workflows (Sligo et al. 2017; Williams et al. 2016). Crucially, these barriers and facilitators not only refer to structural factors, such as the organization's size or ownership status, but first and foremost to the attitude towards innovation and the managerial ability to weave new technologies into the care processes, i.e., establishing process innovation rather than merely adopting product innovation (Cresswell et al. 2017). This also implies that the challenge of "closing the gap" is, at heart, a sociotechnical challenge as the technology has to be synchronized with the sociocultural context of the organization (Sittig and Singh 2010). It is further compounded by the extraordinary complexity organizational HIT systems typically exhibit (Hübner 2015) and the external constraints in terms of economic, demographic, and regulatory pressures health care organizations have to deal with.

Although the importance of the “right” sociotechnical preconditions for fostering the uptake of HIT systems has been pointed to in both the field of medical informatics (Fennelly et al. 2020) as well as implementation research (Liberati et al. 2017), none of the disciplines provide integrated and empirically rooted accounts of the way how to cope with these internal challenges. Respective approaches should embrace the ability of healthcare organizations to innovate in terms of their attitude and culture towards health information technology and their managerial capabilities in terms of information management practices. In the end, it would be necessary to reveal how this ability influences not only the adoption of complex HIT systems but also their quality, i.e., their ability to support care processes. It has therefore been pointed out that corresponding metrics to capture those domains have to be developed (Hübner 2015) and contended that there is a need to integrate those dimensions, i.e., to focus on the interdependencies between technology and its organizational and cultural environment with regard to innovation (van Gemert-Pijnen et al. 2011). Correspondingly, this thesis sets out to address the matter by a stepwise development of a sociotechnical model that provides corresponding constructs and explains the mechanics of the interactions between them while taking into account different legal-financial environments.

To this end, the thesis is structured as follows. Chapter two provides an account of the contextual (2.1.) and theoretical (2.2.) backgrounds. The former includes a more detailed development of the rationale and problem statement by addressing fundamental concepts and backgrounds on the digital transformation in healthcare organizations that relate to issues of organizational innovation capabilities and HIT quality. This is complemented in section 2.2 by a review of the scientific body of knowledge on management approaches, theoretical frameworks, and other empirical models that might be relevant to the topic and problem statement. Next, chapter 2.3 synthesizes the backgrounds and provides a formulation of the research questions along with the conceptual model to guide the empirical works. This is followed by an overview of the research design across the five publications this thesis consists of, a description of the data sources used, and details on the central analytical steps in chapter three. The corresponding results in the form of the five publications are then presented in chapter four. Lastly, chapter five synthesizes the results and illustrates how the various findings across publications integrate with one another, followed by a contextualization and discussion of the main findings, implications for research and practice, as well as the thesis’ overarching limitations and conclusions.

2. Background

2.1. The Digital Transformation in Healthcare Organizations

According to Vial's (2019) definition, the "digital transformation" in healthcare organizations can be understood as a general and evolving process that aims to improve clinical outcomes by triggering significant changes to the care process through the combination of data analytics with Health Information Technology (HIT), medical devices, wearables, etc. Such a process would be, for example, manifested by establishing learning health systems. One key element of this digital transformation is employing HIT – the successful usage of which requires facilitation and management at various levels and through a wide range of means. Primarily focusing on the organizational perspective, the following section expands on HIT, its quality, and detailed challenges with respect to how organizations might enable the uptake of such technologies.

2.1.1. Health Information Technology

There is a multitude of terminologies and definitions used to describe the technologies that underlie the digital transformation in health care organizations (Fatehi et al. 2020) with HIT being arguably one of the most central concept (Agarwal et al. 2010). It can be understood as an umbrella term covering various technologies that store, share, and analyze health information (Kruse and Beane 2018; Yen et al. 2017). In this thesis, HIT is understood more specifically to encompass the organization's electronic information technologies that health care professionals use to support the care process. These include electronic health records (EHRs), health information exchange systems (HIE), computerized provider order entry (CPOE), clinical decision support systems (CDSS), and the related hardware (excluding medical devices) as well as their integration with each other.[1]

The usage of well-integrated and well-designed HIT not only forms the basis and prerequisite for building learning health systems (Miriovsky et al. 2012) and for enabling the shift towards precision medicine (Khoury et al. 2016), but first and foremost serves to support clinical workflows in the sense of providing the right information, for the right person, at the right time, and in the right quality in various care settings (Hübner-Bloder and Ammenwerth 2009; Liebe et al. 2015). Its potential benefits are widely recognized for both gains in efficiency as well as the quality of care (Campanella et al. 2016; Kruse and Beane 2018). Lin et al. (2018), for instance, demonstrated that the adoption of electronic health records (EHRs) in US nonfederal acute care hospitals appeared to have a positive impact on mortality rates, though it seemed to have taken a few years to realize those benefits. However, increased HIT usage does not automatically lead to benefit realizations in terms of quality gains, greater efficiency, or clinicians' work satisfaction. Implementing such systems often poses

[1] A full list of the technologies referred to in this thesis can be viewed in Appendix Table 4 of Publication 1 and Appendix Table 2 of Publication 5.

complex challenges (Greenhalgh et al. 2017) and can, in some instances, even have adverse effects. For example, research on clinician stress and burnout showed that HIT design and use factors such as the inaccessibility of information from multiple institutions, excessive data entry requirements, or poor organizational support and user training, increase the odds of clinicians reporting EHR-related burnout symptoms (Kroth et al. 2019; Eschenroeder et al. 2021).

Nevertheless, in light of the undisputed potential of HIT for healthcare when implemented and designed the right way, the focus in research and practice has shifted from dealing with questions on whether it is worth investing in and promoting the uptake of HIT (Driessen et al. 2013; Thouin et al. 2008; Desveaux et al. 2019) to questions on how higher degrees of successful digitalization can be achieved (Ross et al. 2016; Yen et al. 2017) – particularly in ways that enable HIT to improve processes and outcomes (Plantier et al. 2017; Joseph et al. 2020). Various levels of research can be chosen when tackling this question (Figure 1): the macro-level perspective focusing on governmental policies and the regulatory environment, the meso-level perspective with a focus on internal barriers and facilitators within the healthcare organizations, as well as the micro-level perspective on the technology acceptance and successful use of HIT by individuals. The latter has already been subject to an extensive body of research, especially with regard to technology acceptance (Heinsch et al. 2021). This thesis and the following considerations focus on the macro- and particularly the meso-perspective, which are less researched but promise to provide crucial access points for understanding successful HIT implementations.

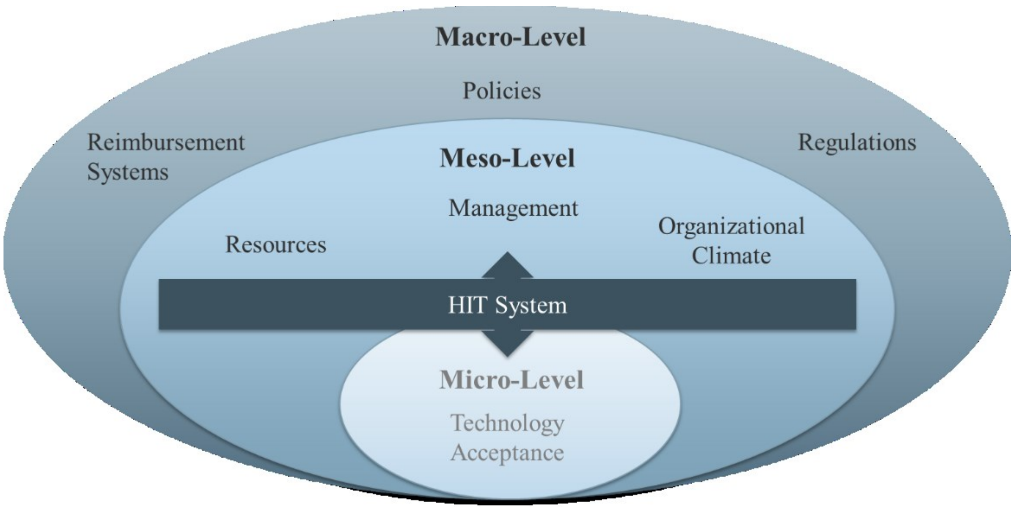

Figure 1: Levels of analysis for the research of implementing HIT systems with exemplary research topics.

2.1.2. Macro-Level Perspective: Policies to Shape the Legal-Financial Environment

Much of the policies and funding that enable the micro- and meso-level to implement HIT effectively originates at the macro-level (Kuziemsky 2017). A favorable environment on this level is considered to encompass a broad range of factors like healthcare governance (e.g. the influence, structure, and encouragement of governing bodies), healthcare standards (e.g. technical and practice standards), societal trends (e.g. the public climate and expectations towards HIT) as well as funding and incentives (Ahmadi et al. 2014; Lau and Price 2017). These factors themselves are contingent on a functioning political system, economy, and health system which allows for resources to be funneled towards such innovation and that can provide resources in terms of hard- and software as well as a well-trained and educated workforce.

Although governmental interventions on this macro-level can take different forms, from time-limited monetary incentives for all or selected healthcare organizations (Halamka and Tripathi 2017; Krasuska et al. 2021), legal obligations to provide certain data electronically (Leyck Dieken 2021), to a complete reform of health care delivery structures (Kierkegaard 2015), particularly the creation of incentive programs and payment schemes have been a popular lever for policymakers in recent decades in many countries (Thiel et al. 2019). Evaluation studies of corresponding programs for hospitals in Germany, South Korea, the US, and China have suggested that when healthcare organizations are left to themselves, i.e., not receiving governmental support or financial incentives for stimulating the uptake of HIT, the diffusion of respective technologies such as EHRs is seriously hampered, leading to considerable differences in adoption rates (Esdar et al. 2019; Kim et al. 2017; Liang et al. 2021). This can likely be attributed to a combination of factors: HIT often takes multiple years to yield positive outcomes (Adler-Milstein; Everson and Lee 2015). This delay in the realization of benefits is exacerbated by the finding that positive outcomes of HIT projects often do not come in the form of immediate financial returns (Ben-Zion et al. 2014; Leidner et al. 2010), which makes it a difficult investment proposal – at least in organizations where executives are primarily driven by economic considerations. Indeed, the financial burden and lack of resources are among the most prominent barriers to adopting EHR systems in hospitals (Jaana et al. 2011; Gagnon et al. 2012). In Germany, for instance, hospitals have been under financial pressure for many years. A strong focus on efficiency emerged in many hospitals in response to introducing the DRG-based financing system that went into full effect in 2009 (Kumar and Schoenstein 2013). Subsequently, many suffered from investment backlogs that were met by an insufficient reimbursement scheme, paired with the political intention to consolidate the hospital sector (Geissler et al. 2014). This likely discouraged many executives from investing in large-scale health IT projects.

The combination of the potential of universal HIT usage for patient care on the one hand, and the finding that the problem of low HIT adoption rates cannot be tackled by a political laissez-faire approach on the other hand, led many countries to launch political initiatives directed at stimulating HIT usage by various means. In the German case, the Hospital Future Act ("Krankenhauszukunftsgesetz" – KHZG) was passed in 2020 in response to this realization (Riedel and Riedel 2021; Bundesgesundheitsministerium 2022). A total of 4.3 billion Euros were made available to hospitals for investing in HIT adoption – specifically in EHRs, patient portals, CPOE systems, CDSS, medication management systems, telemedicine, and other related technologies. The focus of the KHZG primarily lies in facilitating the short- to mid-term adoption while it tends to put less emphasis on their *meaningful use*, i.e., the quality of those systems, which might pose a significant challenge going forward.

However, the effects of the KHZG on the adoption and quality of HIT in German hospitals are not yet foreseeable as of now. When looking at other German-speaking countries for comparison, there are some indications that the political and regulatory environment causes differences in HIT adoption rates between Austria, Germany, and Switzerland, with Austria and Switzerland being regarded as somewhat ahead of Germany in various domains of the digital transformation (Haux et al. 2018; Hübner et al. 2010). Although Switzerland and Austria did not yet launch programs that are comparable to the KHZG specifically, i.e., programs exclusively tailored towards hospitals that feature comprehensive financial incentives, both countries had started to introduce programs to support intersectoral and nationwide use of electronic health record systems, called the Electronic Patient Dossier ("elektronisches Patientendossier" – EPD) in Switzerland in 2015 and the Electronic Health Record ("elektronsiche Gesundheitsakte" – ELGA) in Austria in 2012. While the differences between the countries could also be attributed to disparities in overall healthcare spending as well as other factors related to the healthcare system in general, these programs were considered to be slightly more successfully in stimulating the digital transformation in healthcare organizations compared to the rather passive political approach in Germany up until 2019 (Naumann et al. 2019).

Another prominent example of a large-scale governmental initiative was the Health Information Technology for Economic and Clinical Health (HITECH) Act in the United States in 2009, which was similar to the German KHZG in many respects. The program enabled hospitals to receive incentive payments amounting to roughly $2-10 million per hospital for the adoption and "meaningful use" of EHRs (Jha 2010). Broken down into three stages, stage 1 aimed at adopting eligible EHR systems. Adoption rates subsequently grew from 12.2% in 2009 to 83.8% in 2015 (Henry et al. 2016), which was primarily attributed to the program (Adler-Milstein and Jha 2017), and it was thus deemed successful with regard to this first stage (Gold and McLaughlin 2016; Halamka and Tripathi 2017). Although more recently, Everson et al. (2020) pointed to issues with the accuracy of measuring EHR adoption in the early years, which casts significant doubts on the magnitude of the gains made. Stages 2 and 3 focused on extending the EHR capabilities towards better Health Information Exchange (HIE), patient engagement, and improved outcomes. However, these stages yielded mixed results as the effect of EHR adoption on quality and safety remained uncertain and due to misalignments between the complex program requirements and the organizations' workflows as well as due to insufficiently addressed interoperability issues (Slight et al. 2015; Halamka and Tripathi 2017; Gold and McLaughlin 2016; Kellermann and Jones 2013; Adler-Milstein and DesRoches et al. 2015).

All in all, there are plenty of strategic pathways and timelines that policymakers have pursued to facilitate HIT adoption and successful use with varying degrees of success. Yet, as the US experience has shown, the adoption of HIT can only be seen as the first milestone on the path to building higher quality systems that ultimately aim to improve the quality of care. Many problems persist on this path regarding various unintended consequences borne out of such governmental programs, as witnessed in the HITECH act (Colicchio et al. 2019). Furthermore, while governmental initiatives appear to have been ramped up in the past decades in many nations, they are at risk to be overly prescriptive and might constrain hospitals from moving beyond basic HIT functions to higher-value uses (Halamka and Tripathi 2017; Justinia 2017) as they often cannot take the local specificities and requirements into account. Advances in HIT adoption have also shown to not be equally distributed across organizations since some hospitals managed to make better use of the program than others (Adler-Milstein et al. 2017). Moreover, such programs are typically limited to certain time frames while health information technologies continue to develop and advance, requiring ongoing change and an affinity to innovation in the healthcare organizations they are deployed in.

2.1.3. Meso-Level Perspective: Organizational Issues

Various systematic reviews on the facilitators of HIT suggest that external stimuli and the legal-financial environment hardly suffice to close the gap between the technological potential of HIT and their actual functioning to increase quality in the care processes (Ross et al. 2016; Kruse et al. 2016; Ben-Zion et al. 2014; Sligo et al. 2017; Cresswell and Sheikh 2013; Fennelly et al. 2020). The organizational perspective is discussed to play a crucial role as healthcare organizations act as essential mediators between macro-level environmental pressures (such as regulations, scientific discoveries, or technological developments) and the clinicians' work in the care processes on the micro-level (Beckett et al. 2011). They function as the central entities that provide the organizational structures and procedures through which HIT implementation processes are managed, starting from requirements engineering to post-implementation evaluations (Winter et al. 2011; Arnold et al. 2017). For their part, these organizational structures and procedures are embedded in an organizational culture and climate that can be crucial for successfully adopting innovations like HIT (Wisdom et al. 2014; Cresswell et al. 2017). Generally, reasons for HIT adoption and implementation failures are said to be primarily organizational rather than technical (Kaplan and Harris-Salamone 2009).

To explore these organizational issues surrounding HIT, the following section first expands on the role of healthcare organizations in general and particularly hospitals as useful study objects in this space, before introducing two elementary concepts at the center of this thesis: The notion of HIT quality and innovation capabilities. Although these two concepts eventually manifest themselves in individuals' daily practice on the micro-level, focusing on the meso-level perspective promises to produce findings with greater leverage, i.e., organizational mechanisms that affect large groups of people. Correspondingly, the micro-level is not further detailed in the following.

2.1.3.1. The Translational Function of Healthcare Organization

The mediating function of healthcare organizations between macro-level environmental pressures and the clinicians' work in the care processes on the micro-level can be understood in the broader context of translating basic scientific discoveries and medical innovations into clinical application and improved outcomes (Birken et al. 2017; Woolf 2008) – also known as the continuum “from bench to bedside” (Drolet and Lorenzi 2011). While translational research as a scientific discipline originated from a broader public health perspective, the basic premise equally applies to integrating HIT into clinical workflows and Lehmann et al. (2008) consider it to be a critical challenge for the field of medical informatics. Correspondingly, healthcare organizations are thought to be pressured to address this translational challenge by adapting to developments in medical informatics and technologies (van Rossum et al. 2016). Many scholars repeatedly demonstrated that large health organizations often struggle with this challenge (Asthana et al. 2019; Cresswell and Sheikh 2015; Stephani et al. 2019) which is particularly problematic in light of technical innovation cycles tending to become shorter and shorter in what Glover et al. (2020) call “an innovation age for healthcare delivery”. This further increases the need for healthcare organizations to stay flexible and innovate their HIT systems in ways that maintain or enhance their quality (Piening 2011; Colicchio et al. 2019).

Some healthcare organizations appear to be more successful at this than others since many countries have experienced considerable differences in the levels of HIT adoption (Sabes-Figuera and Maghiros 2013) and their quality (Martin et al. 2019; Liebe et al. 2015) between individual organizations. This underscores the importance of focusing on the organizations themselves in terms of their inner capabilities with regard to innovation promotion, managerial skills, project execution, and the promotion of HIT use (Cresswell and Sheikh 2013; Parthasarathy et al. 2021).

These and related aspects have long been emphasized as critical success factors in conjunction with the resource-based view of explaining organizational performance in general (Barney 1991). This view is not unique to healthcare as other industries face similar struggles in managing large-scale technology projects (Alreemy et al. 2016; Nguyen et al. 2015). However, particularly the restrictive and highly regulated legal frameworks healthcare organizations have to operate under put greater limits on the investment scope and the organizational flexibility in healthcare contexts (Kelly and Young 2017; Duarte et al. 2014; Jaana et al. 2011).

2.1.3.2. Hospitals as Study Objects

While HIT systems need to be embedded and integrated with one another at many different nodes in the care continuum in order to be used as effectively as possible (i.e., in doctors' offices, nursing homes, health insurers), large health care organizations like hospitals play a particularly prominent role (Djellal and Gallouj 2005). Not only do they offer a uniquely diverse range of complex medical and nursing services at a central point of contact with the patient, but they also have a comparably high reach in terms of affected users and patients per HIT-related project. If, for example, a primary care physician decides to integrate their patients' vital data from mobile health apps into their IT system, it has a much lower relative impact than if a hospital embarks on a comparable undertaking with organization-wide effects. Leidner et al. (2010) correspondingly recommend focusing on hospitals, as they can serve as hubs of innovation through which IT solutions can diffuse into other adjacent care settings. However, reliable and nuanced insights into the organizational structures and dynamics that enable effective and innovative information provision in hospitals are scarce and highly fragmented (Cresswell and Sheikh 2013; Greenhalgh et al. 2017). Another factor that sets hospitals apart from other organizations, both within and outside of healthcare, is their characterization as what can be described as “expert organizations” (Rasche and Braun von Reinersdorff 2016). Hospitals employ many highly trained professionals who are often organized in separate clinical units (such as internal medicine, orthopedics, neurology, etc.), which makes managing the digital transformation in those organizations a rather specific challenge (Burmann et al. 2021). This clinic-centeredness has also been shown to potentially hamper innovation when clinical units have a high degree of autonomy, particularly with increasing complexity (Glover et al. 2020). The ability to promote innovation in hospitals has to be, therefore, also considered from a more centralized perspective, i.e., the top management team or the organization at large.

To summarize, in the cascade of translating technological discoveries and solutions into value creation for the patients, healthcare organizations, particularly hospitals, are positioned at a crucial bottleneck which highlights their importance as central entities for research inquiries.

2.1.3.3. HIT Quality and Organizational Innovation Capabilities

Prior research has shown that the structural characteristics of hospitals, such as size, ownership, health system affiliation, and teaching status, are associated with the adoption and use of various HIT systems (DesRoches et al. 2012; Kruse et al. 2014). While these findings are interesting at face value, they are not actionable in the sense that structural characteristics cannot be readily modified and acted upon from a managerial viewpoint. Instead, hospital managers, politicians, and educators could significantly benefit from evidence on organizational levers within the organization's sphere of influence (e.g., management practices, structures, and the culture and attitudes towards innovation). While some strands of research, such as the works on digital maturity models (Carvalho et al. 2016), theoretical papers on implementing change (Weiner 2009) or qualitative investigations (Brewster et al. 2015; Reed et al. 2012; Cresswell et al. 2017) provide guidance on such levers to some extent, the overall evidence base is rather weak, strongly fragmented and lacks well-founded empirical accounts – particularly concerning two overarching themes and their interrelationship: The notion of *HIT quality* on the one hand, and the organizational culture with regard to HIT innovations (hereinafter referred to as *innovation capabilities*) on the other hand.

HIT Quality

Quality requirements of HIT systems can span structural, processual, and outcome-related measures that not only incorporate various technical layers (e.g., data and information, functions, hardware, interoperability) but also features of information management and the perceived quality of the systems (Yusof et al. 2008; Ammenwerth et al. 2007; Winter et al. 2017). Although this separation along structures, processes, and outcomes, as proposed by Donabedian (1988), has its merits to understand the various levels of quality, they are often not easy to distinguish and are intertwined (Tossaint-Schoenmakers et al. 2021). Another perspective on HIT quality offers Delone and McLean's (2003) Information System (IS) success model. They propose a distinction between system quality (i.e., a system's overall performance as perceived by the users), information quality (i.e., the contents and characteristics of the information systems output), and service quality (i.e., the support provided by the IT department). Although the IS success model is thought to have limitations in healthcare contexts (Booth 2012), the inclusion of service quality offers a valuable perspective on HIT quality. This is also picked up by the Japanese-German quality requirements framework of EHRs (QRF-EHRs) in that it explicitly considers information management activities as part of HIT quality requirements (Winter et al. 2017). Information management practices, such as the work and role of the organization's CIO and the IT department, remain overlooked in the literature surprisingly often (Stendal and Dugstad 2017). This lack of recognition of the importance of professional information management practices is particularly astonishing since the CIO's and IT department's main purpose lies in the implementation and development of the organization's HIT systems, and research on information systems in other industries regularly points to their vital role (Mithas et al. 2011; Saldanha and Krishnan 2011).

When focusing on the HIT systems itself, it appears useful to reflect on its primary objective. Many argue this objective lies in what has been coined as *clinical information logistics (CIL)* (Augustin 1990; Hübner-Bloder and Ammenwerth 2009; Haftor et al. 2011; Esdar et al. 2017). The term describes a system's ability to provide the right information for the right person, at the right time, at the right location, and in the right quality, and it has been put forward as a yardstick that HIT systems of high quality should be evaluated against, especially in the context of clinical core processes, such as ward rounds, surgery workflows, and discharge processes (Liebe et al. 2015). In terms of its measurement, CIL might be expressed in both subjective measures of the HIT systems' perceived "fulfillment" of its objective and in the degree to which related technologies are adopted, i.e., CIL's technical manifestations. Regarding the latter, *HIT adoption* is one of the most frequently used terms. As was alluded to above, HIT adoption can be regarded as a necessary yet insufficient condition for drawing conclusions about the quality of a given HIT system[2]. Despite the considerable variation in the definitions found (Yen et al. 2017; Cresswell and Sheikh 2013; Sligo et al. 2017), HIT adoption

[2] In this thesis "HIT system" refers to the totality of the various IT solutions used in a healthcare organization (e.g. EHR, CPOE, CDSS etc.). Definitions in the literature vary greatly. Other common terms are hospital information systems, health information system, clinical information system, eHealth etc.

is most often understood as the implementation, i.e., the introduction and use of an application in the organization (Ben-Zion et al. 2014; Cresswell and Sheikh 2013; Jha et al. 2009). Measuring HIT adoption in and of itself is considered challenging since it requires the incorporation of many different facets of the organization's information system, particularly when focusing on hospitals (Häyrinen et al. 2008; Everson et al. 2014; Pettit 2013; Carvalho et al. 2016). This significantly increases the time and effort required for scale development and data collection. Correspondingly, many studies focus on HIT implementation and adoption in terms of specific functionalities or applications (e.g., Vollmer et al. 2014; Furukawa et al. 2008; Adler-Milstein et al. 2014) or use highly simplified scales about the general perceived level of HIT adoption (e.g., Park and Han 2017; Faber et al. 2017) whereas the complexity of organization-wide HIT solutions is usually far greater.

Lastly, the IS success model, as well as research on EHRs, has suggested that, next to technical manifestations of the information systems, HIT evaluations should also incorporate subjective assessments of the quality of the system as a complementary measure (Mosaly et al. 2016) and ideally include perspectives from both the managerial level and the clinicians' viewpoint (Otieno et al. 2008). However, most measurement approaches, especially in the form of digital maturity models, solely rely on the assessment from a single viewpoint and often exclusively focus on the technical availability of HIT functions while discounting the sociotechnical nature of the environment that HIT needs to be embedded in (Burmann and Meister 2021).

To summarize, the concept of HIT quality can be thought to encompass a broad range of issues. For this thesis, it is understood as…

> *an overarching concept that expresses the degree to which support for clinical workflows can be provided (1) in terms of the HIT system's technical capabilities (the availability of relevant data and information, the adoption of required HIT functions, as well as mechanisms of distribution and integration), (2) in terms of its perceived ability to provide the right information, for the right person, at the right time, the right location, and in the right quality, as well (3) in terms of the degree to which the organization is able to provide the information management practices that are needed to run the systems effectively.*

Innovation Capabilities

HIT quality in healthcare organizations cannot flourish in an organizational vacuum. While professional information management practices might indeed be helpful to foster better information provision in the clinical processes, the work of the CIO and IT department is embedded in a broader organizational context. Various factors matter in this context. But particularly the ability to promote innovation stands out as it has been discussed as a most vital facilitator of HIT (Tsiknakis and Kouroubali 2009; Parthasarathy et al. 2021) and its quality – which is simultaneously considered to be widely under-researched (Allen et al. 2017; van Gemert-Pijnen et al. 2011).

Various definitions have been used to describe the term innovation itself. For example, in exploring the phenomena in the context of the software industry, Edison et al. (2013) identified a total of 41 definitions. Nevertheless, some are more popular than others. Specifically, Everett Rogers' fundamental work on the diffusion of innovation from 2003 included the following, which has been widely recited:

"An idea, practice, or object that is perceived as new by an individual or other unit of adoption" (Rogers 2003).

Another popular definition stems from the so-called Oslo Manual, an international reference guide for collecting and using data on innovation that was first published by the OECD in 1992. The latest edition from 2018 provides the following definition:

"A new or improved product or process (or combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process)" (OECD 2018).

Both definitions share that they distinguish between product and process innovation – although Rogers' only does so implicitly. Process innovations refer to "new or improved processes for one or more business functions" (OECD 2018). It is widely undisputed that product innovations are one of the most vital drivers of economic growth and societal welfare in general (Maradana et al. 2017). Although product innovation can play an important role for healthcare organizations (particularly new medical technologies), their business models do not directly depend on such innovation in the sense that they do not "sell" innovative products directly but rather offer care services within which such innovation may be utilized. Process innovations, on the other hand, are vital for healthcare organizations as they can enable them to realize efficiency and quality gains in care delivery and thus stay competitive (Moreira et al. 2017; Morales-Contreras et al. 2020). In healthcare organizations, the concept of innovation is often considered to be tightly intertwined with HIT (Bygstad and Øvrelid 2020; Arvanitis and Loukis 2016; Parthasarathy et al. 2021), and sometimes the terms are used interchangeably (Leidner et al. 2010; Hübner 2015; Cresswell and Sheikh 2013). In these cases, innovation typically refers to HIT-enabled process innovation, i.e., new and improved ways of health care delivery enabled by digital technologies that are new to the adopting organization. In the long run, it might not be appropriate to continue to simply equate innovation with HIT as the first generations of HIT systems can hardly be recognized as innovations anymore. However, further developments of new and improved health information technologies continue to hold up the promise of tapping further potentials for process innovations – albeit with changing focusses (e.g., from EHR adoption to automated tools to support clinical decisions, image recognition technologies, etc.).

Irrespective of this question on the degree to which HIT can be equated with process innovation, innovation research suggests that the latter should be understood and studied as a function of the organizational capabilities to promote innovation, i.e., innovation capabilities (Edison et al. 2013) and that there is a lack of understanding as to how structural inputs (such as the organizations' size) are transferred into process innovations (Piening 2011). Therefore, the conceptual overlap between process innovation and HIT systems highlights the need to study the relationship between innovation capabilities and HIT in greater detail. This need is reinforced by the many unknowns surrounding the question of how higher degrees of HIT quality may be achieved. It might also be contended that the two domains might not even be compatible at times as some scholars suggest that innovation activities can turn out to be a threat to the quality of a running system (Benner and Tushman 2002; Cole and Matsumiya 2008; Blank and Naveh 2014) which further underscores the advantageousness of researching this relationship.

Studying organizational innovation capabilities presupposes a defining conceptualization. Various elements related to those capabilities have been referred to in the literature under a wide range of terms, such as organizational innovativeness or readiness for change (Ruvio et al. 2014; Weiner 2009), intrapreneurship (Marques et al. 2019), socio-organizational factors (Parolin 2013), (innovation) leadership (Patterson et al. 2009; Weintraub and McKee 2019), managerial capacity for innovation (OECD 2018), organizational climate (Shanker et al. 2017), top management support and attitude (Greenhalgh et al. 2004), organizational culture (Rajapathirana and Hui 2018), and more.

Hurley and Hult (1998) view the innovation capabilities of an organization as "the ability of the organization to adopt or implement new ideas, processes, or products successfully", which is seen as a cultural precursor and readiness that provides the 'social capital' to facilitate innovative behavior (Hurley et al. 2005). In this thesis, innovation capabilities are defined more specifically as…

> *the organizational climate regarding HIT at various organizational levels that reflects its ability to innovate, that is, the ability to adopt new HIT solutions (or renew the existing ones) that enhance the quality of information provision in clinical care processes.*

Crucially, this definition recognizes that different organizational levels (such as the top management team, but also the IT department as well as the organization at large) should be considered when focusing on HIT-based innovation.

Notwithstanding minor conceptual variations, all of the abovementioned terms and definitions share the fact from a measurement point of view that they essentially express latent phenomena – meaning they are inherently difficult to capture as they are expressions of a commonly shared attitude of a social network that leads to certain sets of corresponding behaviors (Caccia-Bava et al. 2006; Tuan and Venkatesh 2010). Such latent phenomena are more generally referred to as *constructs*, i.e., "the abstract idea, underlying theme, or subject matter that one wishes to measure" (Lavrakas 2008). They are typically measured by a set of underlying question items that refer to different expressions of the construct. Despite little consensus on terminologies and measurement approaches in this space (Lynch et al. 2010; Wisdom et al. 2014), there are some recurring themes in the innovation literature that can be assumed to be expressing organizational innovation capabilities, such as openness towards innovation, future orientation, proactiveness, risk-taking, and creativity. But the few scales that have been put forward to capture these aspects (e.g., Ruvio et al. 2014) are largely incompatible with the specific characteristics and demands of healthcare organizations and health information technologies, e.g., the multi-professional environment with regard to the role of clinicians or the fact that value is created through care delivery rather than manufacturing processes. Correspondingly, many have pointed to the need for further work to examine this construct and its measurements (Allen et al. 2017; Wisdom et al. 2014; Hübner 2015).

All things considered, the notion of HIT quality as a function of organizational innovation capabilities might offer a valuable perspective on the digital transformation of healthcare organizations. However, their constituents and relationship in the context of macro-level environmental pressures and meso-level structures remain largely underexplored to date. To assess whether such a relationship can be observed systematically on an inter-organizational, population-level basis, a quantitative approach appeared best suited and advisable. Furthermore, there already were some closely related studies based on qualitative data (Brewster et al. 2015; Reed et al. 2012; Cresswell et al. 2017; Greenhalgh et al. 2017). Using a quantitative approach, claims about relationships between innovation capabilities and HIT quality can also be readily validated and tested. Furthermore, by including healthcare organizations from multiple countries, the influence of the legal-financial environment could additionally be controlled for to further generalize the findings.

2.2. Theoretical Background on Management Approaches, Frameworks, and Empirical Models

Several theoretical considerations from the fields of health informatics, management research, implementation research, information systems research, and sociology might offer backing for understanding and contextualizing the relationship between innovation capabilities and HIT quality in healthcare organizations. Therefore, the following section reflects on potentially relevant management approaches, theories on HIT in organizational settings, as well as on related empirical models and explores their utility for this research.

2.2.1. Management Approaches

Several management approaches can be assumed to bear some overlap with what has been defined as organizational innovation capabilities above. Some of the more prominent approaches that have been applied in healthcare management research and practice are various forms of strategic management, change management, and lean management.

Strategic Management

Having dedicated IT strategies in place is known to facilitate HIT adoption and might also have some association with the innovation capabilities of hospitals (Liebe et al. 2017; Liebe et al. 2012). The relevance of strategic approaches to information management in healthcare organizations is widely recognized (Winter et al. 2011). Recent studies found specific HIT strategies to be beneficial for certain types of information systems – such as the extensive engagement of the executive board for the adoption of advanced patient engagement functions (Holmgren et al. 2021), the focus on integrating various subsystems for being able to conduct advanced clinical data analysis (Holmgren et al. 2021), the participation in HIE networks to improve hospital operational performance (Walker

2018), or the engagement of clinicians for successful HIT implementations (Ingebrigtsen et al. 2014; Silow-Carroll et al. 2012; Sligo et al. 2017). However, specific IT strategies are often context-dependent (Holmgren et al. 2021) as they have to be tailored towards the peculiarities of the specific organization in question, the legal-financial environment it operates in, and the type of HIT system or function. Therefore, their effect can hardly be generalized. This again calls for a focus on the more general organizational environment concerning the culture towards HIT innovation within which strategies are deployed. Yet, applying IT strategies in principle might still be a defining part of what makes for professional information management practices.

Change Management

In the Oslo Manual on innovation, the OECD suggests that 'Change management capabilities are closely related to an organization's innovation capability' and identifies responsiveness, creativity, alignment, and learning as the defining domains of change management (OECD 2018). Cresswell and Sheikh (2013) also note the relevance of change management as one of the principal knowledge domains surrounding organizational issues in HIT innovation. However, in reviewing the past application of change management in healthcare management research, Harrison et al. (2021) showed that change management models such as the ones of Lewin (1947) and Kotter (1996) are primarily used to guide change agents in local-level, single-unit, or single-site quality improvement projects rather than inter-organizational, population-level assessments. While many studies that applied structured change management models reported successful change, they were not able to detect whether the use of a model, method, or process actually contributed to the success (Harrison et al. 2021). Similarly, Weiner (2009) notes that "theories and approaches to change management currently available to academics and practitioners are often contradictory, mostly lacking empirical evidence and supported by unchallenged hypotheses" – a claim also reiterated by Barends et al. (2014) who outright conclude that scholars and practitioners should be skeptical regarding the body of research in this field in general. However, some core principles from the change management literature might nevertheless be helpful for researching HIT quality. In this regard, Harrison et al. (2021) highlight common principles of involving people in change from the outset and supporting change through good communication and collaboration behaviors. Also, Boonstra and Broekhuis (2010) conclude from their research on EHR implementation that a strong culture with a history of collaboration, teamwork, and trust between different stakeholder groups minimizes resistance to change in HIT-related projects and note that this is indeed loosely in line with the broader change management literature. Overall, however, very few studies explicitly employ change management models on HIT-related issues (Suc et al. 2009), and their usefulness for population-level assessments that go beyond single-site guidance appears to be limited.

Lean Management

With the onset of the growing prominence of economic principles and efficiency considerations in healthcare delivery, lean management gained popularity in recent years as a seemingly universal tool for improving processes in healthcare organizations (McIntosh et al. 2014). It refers to “the application of ‘lean’ ideas in healthcare facilities to minimize waste in every process, procedure, and task through an ongoing system of improvement” (Catalyst 2018). Although the research on lean principles in relation to HIT is scarce, some studies suggest that lean management might be beneficial for HIT (Shortell et al. 2021; Blijleven et al. 2017) and potentially for leveraging innovation (Abuhejleh et al. 2016). However, other research notes certain incompatibilities between lean principles and innovation capabilities (Chen and Taylor 2009; Abdallah et al. 2018) and evidence that casts doubt on the effectiveness of lean management principles in healthcare altogether started emerging in recent years (Chan et al. 2020; Botschmanowski et al. 2021).

2.2.2. Theories on HIT in Organizational Settings

Bridging perspectives on the technical manifestation of HIT in healthcare organizations (in terms of the adoption of certain types of functions, availability of hardware, data as well as their integration across systems) with latent characteristics such as the innovation capability of an organization suggests taking a socio-technical perspective on how to attain HIT quality. Many different theories from different disciplines (medical informatics, sociology, implementation research, information systems research, and management research) have been used to study HIT implementation and related issues through a fundamentally socio-technical lens, i.e., acknowledging the interplay of social entities (such as organizations) and technology. Heinsch et al. (2021) conducted a comprehensive review of theories informing HIT implementation. They identified 36 different theories and classified them by drawing on the typology by Sovacool and Hess (2017) for theories of sociotechnical change as either structural, agency-centered, relational, or meaning-centered. Most notably, they found the distribution of the classified theories to be heavily skewed towards an overrepresentation of agency-centered theories that focus on individual beliefs, actions, and attitudes, particularly on predicting or explaining end-user acceptance without consideration of the environmental context. Theoretical perspectives that capture the organizational structures and relationships required to enact sustainable change (i.e., structural theories) were less well represented but are decidedly more appropriate in the context of this thesis.

The following section introduces the most important structural theories[3] drawn from Heinsch et al. (2021), from Georgiou et al.’s (2019) work on interdisciplinary theory in health informatics, as well as from some additional theories that are potentially relevant in the context of this study. The section also reflects on their strength and shortcomings generally, and in the context of this research specifically. Table 1 below provides an overview of all selected theories.

[3] Some of the following might not fully qualify as theories, but rather frameworks (e.g. CFIR). For simplification purposes, all are refered to as “theoretical frameworks”. The abovementioned QRF-EHRs from Winter et al. that pointed to the need of including information management as part of HIT quality is not included in the list as it does not aim to be a theoretical framework. Nevertheless, it informed the conceptual model described in chapter 2.3.

Diffusion of Innovation (DoI) Theory

The diffusion on innovation theory founded by Everett Rogers in 1962 (Rogers 2003) is arguable the most prominent theory in researching innovation. It primarily focuses on the diffusion of innovation in social systems over time. Although organizational issues are represented to some extent, it is mainly centered around individuals and concerns about its specific usefulness in organizational settings have been raised (Lundblad 2003; Kiwanuka 2015). DoI has been subject to numerous applications across disciplines, with each study applying it in slightly different ways. This lack of cohesion is thought to have left the theory stagnant and difficult to apply with consistency to new problems (Wejnert 2002). In the context of healthcare, Greenhalgh et al. (2017) caution the need to be aware of the many complex factors in healthcare processes and that DoI is at risk of missing critical predictors of innovation adoption in this space which has given rise to other, more specific models.

Technology–Organization–Environment (TOE) Framework

The TOE Framework originated from the field of information systems research and appears specifically useful in the context of this thesis as it recognizes the interplay of the organizational, environmental, and technical dimensions in researching technology adoption in organizations. It was developed by Tornatzky and Fleischer (1990) in their work on technological innovation and has been implemented by many researchers for different technology innovations over the years. However, it is thought to have undergone little theoretical development since its introduction (Li 2020), which some account to it being too generic with too many degrees of freedom in terms of varying factors and measures (Zhu and Kraemer 2005). Alharbi et al. (2015) similarly note that it often does not contain all variables in each context and that for researching complex HIT (cloud computing in their case), more than one theoretical perspective is required to express a better understanding of the adoption decision.

Information Systems (IS) Success Model

The IS success model developed initially by Delone and McLean in 1992 (Delone and McLean 2003) is one of the most popular theories in information systems research and has been used for HIT in organizational contexts (Bossen et al. 2013) as well. It seeks to provide an understanding of the successful use of information systems by identifying, describing, and explaining the relationship among six dimensions (information quality, system quality, service quality, system use, user satisfaction, and net system benefits). However, it does not recognize organizational-level antecedents of the model's dimensions, and it has been criticized for its lack of sociotechnical sensitivity in HIT research (Booth 2012). Its drawbacks in the context of HIT have led to the development of healthcare-specific model extensions, namely the Clinical Adoption Framework and the HOT-Fit Framework (Lau et al. 2011; Yusof et al. 2008).

Clinical Adoption Framework (CAF)

Based on the critique of the former theories about their unsuitability for healthcare contexts, several scholars in the field of health informatics have come to develop more specific theoretical frameworks. One of these frameworks is the Clinical Adoption Framework (CAF), proposed by Lau et al. (2011). It is essentially based on the IS Success Model but additionally incorporates a set of meso- and macro-level factors that are theorized to be critical for HIT success. It has been applied in over 30 HIT studies, yet mainly in the context of primary care and not as an instrument for quantitative assessments (Lau and Kuziemski 2017). However, the CAF is considered to be difficult to apply as there is no guidance documentation with specific descriptions and rules regarding its use, leading to differing interpretations and applications (Craven et al. 2016; van Mens et al. 2020). Furthermore, while the meso-level recognizes organizational-level factors relating to the culture and strategy, those dimensions are not expanded upon and fall short of capturing innovation capabilities as they were defined above.

Human, Organization, and Technology–Fit (HOT–Fit) Framework

Another similar framework that originated from health informatics in 2008 is Yusof et al.'s (2008) HOT-Fit Framework, which builds on the IS success model but is more widely received than the CAF as measured by citations. Unlike CAF, it does not include macro-level factors but also strongly emphasizes the organizational perspective in HIT research – although it does not recognize organizational innovation capabilities either. Its primary advantage lies in its suitability for empirical quantitative assessments as it allows the derivation of more or less specific hypotheses pertaining to the relationships between its domains. However, studies that set out to test corresponding hypotheses using survey-based methods found that most of the proposed relationships did not hold up to scrutiny, thus calling the validity of the framework into question (Erlirianto et al. 2015; Ahmadi et al. 2017).

Nonadoption, Abandonment, Scale-up, Spread, and Sustainability (NASSS) Framework

The NASSS framework is the latest theoretical framework in the list that emerged at the intersection between health informatics and implementation research in 2017 (Greenhalgh et al. 2017). It has been developed to fill a gap in the literature on technology implementation by specifically moving beyond the isolated notion of adoption and focusing also on "*nonadoption, abandonment of technologies and the challenges associated with moving from a local demonstration project to one that is fully mainstreamed and part of business as usual locally (scale-up), transferable to new settings (spread), and maintained long term through adaptation to context over time (sustainability)*" (Greenhalgh et al. 2017). The framework covers a wide range of factors relevant to technology implementation and asserts the crucial role of varying degrees of complexity among those factors and the technology itself. It thereby also explicitly points to the importance of an organization's capacity to innovate but does not pick up on the notion of HIT quality. NASSS's usefulness for quantitative assessment is limited at this point due to the framework's relatively broad scope and high level of abstraction. An assessment tool to enhance the framework's practical usefulness called NASSS-CAT is currently in development but has not yet been tested (Greenhalgh et al. 2020).

Consolidated Framework for Implementation Research (CFIR)

Several theories have emerged from implementation research over the past years with CFIR likely being the most influential. It is a meta-theoretical framework that was developed to guide systematic assessments of multilevel implementation contexts to identify factors critical to intervention implementation and their effectiveness (Damschroder et al. 2009). The CFIR provides an overarching typology containing five major domains: intervention characteristics, outer setting, inner setting, and characteristics of individuals and processes. It is said to provide a comprehensible *"menu"* of domains, sub-domains, and underlying success factors but does not consider or make assumptions as to how these domains might be interrelated or how change occurs (Heinsch et al. 2021). CFIR does also not provide consented scale sets – although there have been independent developments of measurement scales for some of the domains that also bear some conceptual congruence to organizational innovation capabilities (Fernandez et al. 2018). While it has been applied to HIT (e.g., Varsi et al. 2015), its basic premise as a general implementation framework implies a broader scope, so it does not consider challenges specific to HIT quality.

Normalization Process Theory (NPT)

In contrast to CFIR, NPT focuses on the implementation process by which new technologies and other complex interventions are routinely operationalized in everyday work and sustained in practice. It was first published in 2009 by May et al. (2009) to serve as an explanatory model to help managers, clinicians, and researchers understand these processes. Based on mechanisms that had been empirically demonstrated to influence implementation processes and their outcome, May et al. (2009) highlight the social processes through which interventions are operationalized. This is broken down into four categories: coherence, participation, collective action, and reflexive monitoring. Although its primary application lies in qualitative research and informing systematic reviews (Murray et al. 2011; McEvoy et al. 2014), a survey dedicated to assessing implementations through the lens of NPT quantitively has recently been developed (Rapley et al. 2018; Finch et al. 2018). While useful for studying the routinization of specific interventions from the clinician's viewpoint in a given setting irrespective of macro-level influences, it is neither suited for multi-organizational research designs nor for researching complex HIT systems. Furthermore, the theory's relatively narrow focus on the routinization process was one of the prompts for developing extended frameworks such as the NASSS.

Theory of Organizational Readiness for Change

Weiner's theory of organizational readiness for change, which he also published in 2009 (Weiner 2009), is unique in the field of implementation research as it solely focuses on the organizations' viewpoint and their capacity for managing change by proposing a model that entails determinants (such as change valence or task demands) and outcomes (such as the implementation effectiveness) of the organizational readiness for change. He developed a view on critical change management issues in health organizations that contains relatively specific, and thus testable, assertions while also pointing to the need to test such theories using a multi-organizational research design instead of single-center or department-level studies. The latter, however, is challenging to realize due to the theory's premise of trying to capture underlying domains such as change valence or change commitment on the level of individual clinicians. Weiner, therefore, states that respective studies would require multi-level methods by determining within-group agreement statistics first and then aggregating them for intra-organizational analysis – something only a few studies have realized thus far (Shea et al. 2014). But more importantly, the theory takes a comparably narrow approach to change management: It explicitly precludes contextual factors such as an "organizational culture that embraces innovation", i.e., factors that would be considered to be reflecting innovation capabilities as it is understood in this thesis. Similar to NPT and CFIR, it too is primarily designed for one-off type implementation projects rather than for the more multifaceted and evolving nature of complex HIT systems.

Resource-Based View (RBV)

The RBV is a business management framework that emphasizes the strategic resources a firm can exploit to achieve sustainable competitive advantage. Although this view is said to have roots in many different works across the past century (Lowe and Teece 2001), Barney's article from 1991 on firm resources and sustained competitive advantage is widely considered to be the pivotal work in the emergence of the RBV (Barney 1991). The RBV rests on the premise that managerial attention should be placed on the organization's internal resources to identify those assets, capabilities, and competencies with the potential to realize superior competitive advantages. Many see it as the counterpart (or complement) to the outward-facing market-based view that considers the environmental factors and market forces the primary determinants of business performance (Makhija 2003). While this rather generic view does not offer much for researching HIT quality in relation to organizational innovation capabilities specifically, the basic premise of "facing inwards" indeed underscores the importance for healthcare organizations to exploit and rely on their inner capabilities (such as the innovation capabilities) to deliver health care services successfully.

Upper Echelon Theory

Another useful theoretical perspective in this context is reflected in the Upper Echelon Theory. It stemmed from the field of management research and was first introduced by Hambrick and Mason (1984). They essentially also take a resource-based view but specifically emphasize the influence of the top management team on organizational performance and innovation. Although the primary focus lies on the background characteristics of the top management teams (TMT) and how they affect business outcomes, the theory extends to the top managers' values and attitudes which are thought to affect innovation outcomes and IT adoption (Awa et al. 2011), thereby providing potentially valuable clues as to the critical role of the TMT in shaping and propagating an innovation-friendly climate throughout the organization.

Sociotechnical Systems (STS) Theory

The STS theory is a rather generic sociological theory whose roots are traced back to Trist and Bamforth's work on English coal mines in 1951 (Pasmore et al. 1982; Trist and Bamforth 1951). It can be applied to various topics but has mostly been used in the context of organizational and work design research. It is neither related to HIT nor to innovation capabilities, but the theory's basic proposal, namely that social and technical aspects have to be viewed as intertwined and studied congruently to optimize the design and performance of any organizational system, lies at the foundation of almost all of the theories above. STS theory aims to assist with what is called *joint optimization*, that is, designing the social and technical systems in an organization in a way that ensures seamless integration between the two by considering several organizational subsystems pertaining to the relationship between people, tasks, technologies, and structures (Leavitt 1965). However, the term *sociotechnical* itself is used in a broad sense as almost any kind of organization comprises people and technology, leading to fuzzy boundaries and some degree of arbitrariness of what can be subsumed under STS theory and what not. The theory has loosely been applied for studying HIT in healthcare organizations (Booth et al. 2017; Aarts et al. 2010) but has also received criticism for underemphasizing "material" matters such as the physical, legal and budgetary environment in hospitals which led Fernando and Dawson to propose an extended "Socio-Technical-Material perspective" for these contexts (Fernando and Dawson 2014).

Institutional Theory

While Institutional Theory draws on insights from several early social theorists like Max Weber and Émile Durkheim, it was primarily shaped and first developed by Scott, Meyer, and colleagues in the 1970s (Meyer and Rowan 1977; Scott 2005). The theory essentially describes how social structures (rules, norms, routines) act as *authoritative guidelines* for social behavior. Taken into the organizational context concerning HIT, it posits that an organization's environment (such as the cultural belief system or normative and regulatory systems that aim to provide meaning and stability) can strongly influence the development and use of HIT – often more so than market pressures can (Sherer et al. 2016; Heinsch et al. 2021). Institutional effects are thereby thought to be dispersed through *isomorphic pressures*, i.e., the mimicking of other similar organizations' behavior which typically leads all actors in one system to converge onto a very similar set of behaviors or strategies. This notion of isomorphism resembles the imitation effect theorized as part of Rogers' (2003) DoI, but its applicability in HIT appears somewhat limited as there still is considerable variation (i.e., low degrees of convergence) in the adoption and successful use of HIT in healthcare organizations. Notwithstanding the drawbacks with regard to the notion of isomorphism, Institutional Theory still provides a valuable perspective for it acknowledges the importance of organizational norms and particularly the shared values and social structures organizations provide for shaping HIT use.

Scott et al. (2019) recommend that theories for research related to health informatics should be considered based on selection criteria that fit the research project at hand. Following their suggestion, the theoretical frameworks were evaluated against the core requirements that follow from the deliberations in the previous chapters: (1) that the theory considers innovation capabilities or parts thereof as it has been defined above, (2) that it considers HIT quality or parts thereof, (3) that it is suited for quantitative assessments on an inter-organizational level, and (4) that it proposes relationships between its elements. Table 1 summarizes to what extent the theories fulfill these four requirements as judged by the author. A check mark indicates that the requirement is met: For example, the NASSS framework explicitly refers to organizational innovation capabilities (although providing a rather vague description of it), the CAF explicitly refers to the quality of the HIT system and not just the system itself, the NPT and related research provide scale sets to conduct quantitative research, and the HOT-Fit framework specifies relationships between its elements. A checkmark in brackets indicates situations where the theory fulfills the requirement to a small extent or not explicitly: For example, The TOE Framework refers to organizational issues that might include organizational innovation capabilities but is not explicit about it, the IS success model refers to information system's quality but not related to health IT, Rogers' DoI theory has been used for quantitative assessment although it does not provide scales for inter-organizational research, and institutional theory suggests that the organization's environment can influence HIT use without being explicit about how this association might be specified.

Table 1: Theoretical frameworks for researching HIT in organizational settings.

Theoretical Framework	**Discipline**	**Considers innovation capabilities or parts thereof**	**Considers HIT quality or parts thereof**	**Suited for quantitative assessments on an inter-organizational level**	**Provides relationships between theoretical elements**
Diffusion of Innovations (DoI) Theory (Rogers 2003)	Interdisciplinary	✓		(✓)	(✓)
Technology–Organization–Environment (TOE) Framework (Tornatzky and Fleischer 1990)	Information Systems Research	(✓)	(✓)	✓	✓
Information Systems (IS) Success Model (Delone and McLean 2003)	Information Systems Research		(✓)	✓	✓
Clinical Adoption Framework (CAF) (Lau et al. 2011)	Health Informatics	(✓)	✓	(✓)	(✓)
Human, Organization, and Technology–Fit (HOT–Fit) Framework (Yusof et al. 2008)	Health Informatics	(✓)	✓	✓	✓
Nonadoption, Abandonment, Scale-up, Spread, and Sustainability (NASSS) Framework (Greenhalgh et al. 2017)	Health Informatics	✓	(✓)	(✓)	(✓)
Consolidated Framework for Implementation Research (CFIR) (Damschroder et al. 2009)	Implementation Research	✓		✓	

Normalization Process Theory (NPT) (May et al. 2009)		(✓)		✓	(✓)
Theory of Organizational Readiness for Change (Weiner 2009)		(✓)		✓	✓
Resource-Based View (RBV) (Barney 1991)	Management Research	(✓)			
Upper Echelon Theory (Hambrick and Mason 1984)		(✓)			(✓)
Sociotechnical Systems (STS) Theory (Trist and Bamforth 1951)	Sociology		(✓)	(✓)	
Institutional Theory (Scott 2005)		(✓)			(✓)

(✓) = not explicitly or to a small extent

The presented theories offer several access points and frames for studying HIT in organizational settings. However, all exhibit substantial drawbacks or mismatches in relation to the specific challenge of combining views on the innovation capabilities of an organization with its HIT quality using an empirical, quantitative approach. Generally speaking, the theories originating from implementation research focus on new ways of conducting healthcare and do not consider the specifics of HIT or HIT quality. On the other hand, theoretical frameworks in the field of health informatics often do not seriously consider organizational innovation capabilities or management-related issues, whereas management research does not cover HIT-related considerations. Meanwhile, theories from the field of information systems research exhibit drawbacks in healthcare contexts, and sociology theories only offer very broad frames and are thus limited in providing concrete guidance or predictions for this research. It is particularly noteworthy that none of the theoretical frameworks account for the role of professional information management – despite its crucial function for building and maintaining high-quality HIT systems, as has been argued in chapter 2.1.3.3. The insufficiencies of existing theoretical frameworks for HIT research might also be attributed to the fact that theory has traditionally not played a dominant role in health informatics. Scott et al. (2019) accordingly bemoan the apparent under-utilization of theory to explain changes or help predict outcomes and call for a nudge towards greater theory usage, development, and adaptation in the field. This also points to the need for an interdisciplinary approach in researching the relationship between organizational innovation capabilities and HIT quality that draws on various theoretical underpinnings.

2.2.3. Empirical Models

Structural Models

Next to pertinent management approaches and theoretical frameworks, a few empirical models based on primary research have been proposed that address some of the challenges related to innovation capabilities and HIT quality. For example, in one study, Erlirianto et al. (2015) fitted an empirical model that closely followed the specifications suggested by Yusof et al.'s HOT–Fit Framework. They tested the model based on survey data obtained from 87 EHR users in an Indonesian hospital but rejected most hypotheses, which raises doubts about the framework's usefulness.

Leidner et al. (2010) choose a more specific focus on IT innovation in hospitals, seeking to understand why certain hospitals are "IT innovators" and how that relates to hospital performance. The resulting model is loosely rooted in the RBV but combines several theoretical views, including the upper echelon perspective, to derive the model specifications. Based on data obtained from CIOs and CEOs of 70 US hospitals, they found the "top management team's attitude towards IT" and the "CIO strategic leadership" to influence the perceived degree of IT innovation and link IT innovation to increased hospital performance. Although the model partly reflects the notion of organizational innovation capabilities and showcases its potential relevance for HIT, it does not consider the actual degree of HIT adoption and the system's quality. Instead, the authors operationalize "IT innovation" merely by asking the respondents to what degree they perceive the hospital to be innovative concerning IT using Likert scales. A similar issue appears in the models proposed by Parthasarathy et al. (2021) and Paré et al. (2020). Parthasarathy and colleagues link an organization's perceived ability to deploy product and process innovation to its perceived HIT success as measured by items that indicate the respondent's assessment of whether a hospital's EHR is, for instance, "effective" or "reliable". However, they do not assess manifest attributes of the EHR. Similarly, Paré et al. (2020) investigated the role of IT management and IT centrality in affecting the degree to which IT contributes to organizational performance as perceived by the CIOs of 72 Canadian hospitals.

Another study by Faber et al. (2017), which is loosely based on theoretical considerations from Rogers' DoI, the TOE Framework as well as the RBV, highlights the significant influence of the organization's size as well as the degree of top management support of IT for eHealth adoption rates in 30 Dutch hospitals. While they consider the availability of specific HIT functions in those hospitals for measuring "eHealth adoption", these functions only refer to the adoption of telemonitoring in heart failure, telemonitoring in diabetes, and online access to EHRs as measured by three single-scale items, thus offering a very limited and incomplete picture of hospital's HIT systems.

All in all, the models presented here are particularly limited with regard to their sample size and a predominantly narrow notion of innovation capabilities. Also, none offer views on the role of the legal-financial environment on the macro-level. More importantly, however, they do not do justice to HIT systems' complex and multifaceted nature as they only address some fractions of HIT quality.

Digital Maturity Models

The challenge of capturing the complexity of HIT in healthcare organizations for both internal strategic information management as well as for scientific purposes gave rise to the development of digital maturity models. These models typically aim to assess the maturity of HIT by considering an extensive array of functions and constituents of the HIT system under study. While many models operationalize and measure particular maturity aspects such as picture archiving and communication systems (PACS), telemedicine services, or systems to ensure the continuity of care, very few cover all organizational areas and systems of healthcare organizations (Carvalho et al. 2016). One of the most well-known maturity models is the Electronic Medical Record Adoption Model (EMRAM), developed by the Healthcare Information and Management Systems Society (HIMSS) (Pettit 2013). It has widely been used as a benchmark measure in assessing EHR adoption across hospitals and countries (Kose et al. 2020; Stephani et al. 2019), but it also has been faulted for lack of transparency regarding its design and structure (Liebe et al. 2015). More importantly, it received criticism for its limited focus on EMRs which causes it to disregard vital aspects of high-quality HIT systems, such as the capability to communicate and share standardized data with other health providers (Cresswell et al. 2019). The IT Report Healthcare (Hübner et al. 2018) and the associated Workflow Composite Score (WCS), in contrast, are recognized as a maturity model that addresses this issue by using a broader approach that accounts for the variety of HIT systems in several organizational areas (Burmann and Meister 2021).[4]

Notwithstanding their "technical" scope, most maturity models tend to neglect the dependence of HIT-supported healthcare processes on social and sociotechnical interactions in their organizational context (Burmann and Meister 2021). Although it can be argued that such perspectives lay outside of what maturity models primarily try to achieve, the lack of consideration of factors like management, the organizational culture, or innovation capabilities has led to calls for reconceptualizing digital maturity models (Cresswell et al. 2019). Therefore, maturity models might be useful for capturing the technical manifestation of HIT quality but are generally insufficient to study HIT quality in a broader socio-technical context by itself.

2.3. Research Questions & Conceptual Model

The digital transformation in healthcare organizations is a multifaceted issue that requires research on many levels which might draw on various theoretical frameworks. Whereas the macro-level top-down perspective is important to understand the political and regulatory environment within which healthcare organizations act and might explain some differences between organizations in different countries, it does not offer sufficient explanations as to why some organizations exhibit higher degrees of digital maturity and better IT support of the care processes than others. This warrants an increased focus on the organizations and the individual actors within them. The latter perspective on the individuals and their acceptance and successful use of HIT, i.e., the micro-level perspective, has been subject to an extraordinarily large body of research activities in the past decades, particularly addressing the individual and interpersonal element of technology acceptance (Heinsch et al. 2021; Ammenwerth 2019). Therefore, the marginal gains of further research can be expected to be relatively low.

[4] The WCS is utilized as a central tool for measuring HIT quality in this thesis. Although it can be regarded as a maturity model, it will not be referred to as such in the following for the sake of more consistent terminology usage.

Meanwhile, focusing on organizational settings, i.e., the meso-level perspective, is thought to have been neglected in research surprisingly often (Greenhalgh et al. 2017) – with the exemption of the influence of structural characteristics such as the organization's size and ownership status on HIT adoption. This is particularly notable given the organization's unique and crucial positioning in the translational trajectory of bridging the gap between the potential of innovative HIT systems and their effectiveness within the care processes. Also, many organizations fall short of carrying out this translation which calls for scrutinizing pertinent success factors and organizational levers.

The previous deliberations also highlighted that innovation capabilities, as well as the management and quality of HIT, could be assumed to be central forces in the digital transformation in healthcare organizations and thus offer valuable perspectives for analysis at this level. To date, however, there is little understanding about how these factors can be conceptualized in detail, measured, and how they are interlinked. The existing theoretical frameworks, management approaches, and empirical models offer little to incomplete insights into this perspective. More specifically, there is a gap in the literature on how the attitude and culture towards IT-based innovation in healthcare organizations may help foster higher degrees of HIT quality in the care processes and what role professional information management plays within this relationship. Research directed at closing this gap requires that the core constructs not only have to be defined and conceptualized but also that comprehensive measurements must be developed to capture the subject's complexity adequately. Therefore, this thesis sets out to address the matter in terms of two primary research questions:

1) What constitutes innovation capabilities of healthcare organizations as well as the professionalism of their information management, and how can corresponding constructs be measured?
2) How do innovation capabilities and the professionalism of information management influence measures of HIT quality in terms of workflow support and perceived quality in healthcare organizations under consideration of their respective legal-financial environment?

The first research question refers to the need to develop the constructs and corresponding measurements necessary for addressing the second research question. This specifically applies to the organization's innovation capabilities and information management. For HIT quality, previously developed constructs and measurements (Esdar et al. 2017) could be drawn upon and did not need to be developed from the ground up.

As was argued in chapter 2.1.3, all domains of interest, including the HIT quality, contain multiple sub-dimensions that must be assumed to have several interrelationships and dependencies with one another in various ways. To account for this conceptual complexity, the thesis aims to address Research Question 2 by means of developing and testing an empirical, sociotechnical model that integrates the different constructs and their sub-dimensions with one another and seeks to understand their interrelationships.

Conceptual Model

Developing a model that addresses the complexity implicated in the two research questions requires the proposition of a conceptual model that provides a basis for (1) structuring the elementary constructs and sub-dimensions and (2) for proposing fundamental linkages between them to allow for empirical testing.

With the premise of researching HIT at the organizational level, this thesis takes a structural rather than agency-centered approach: It presumes the organization to be a provider of the technical and social structures which determine successful HIT use as is similarly conceptualized in the Institutional Theory. The conceptual model for addressing the research questions thereby essentially rests on the notion of understanding the digital transformation in healthcare organizations as a sociotechnical challenge. While this draws on the fundamentals of the sociotechnical systems theory, it must be noted that none of the theoretical frameworks described above offer a satisfactory fit to the research questions specifically. Although there might be a risk of compromising consistency when not drawing on one theory exclusively, instances of absence of suitable theory typically warrant combining elements from various theoretical frameworks. Some argue that "triangulating" theoretical perspectives to conduct empirical research can be beneficial for better mitigating the risk of falling into "theoretical monogamy and dogmatism" (Sovacool and Hess 2017). Correspondingly, the conceptual model echoes several common themes that emerge from the theories and empirical works described above (Figure 2). It thereby reflects an interdisciplinary approach rooted primarily in health informatics but also draws on theories from other disciplines in light of the rather weak and somewhat incomplete theoretical and empirical foundations this field provides for addressing the research questions.

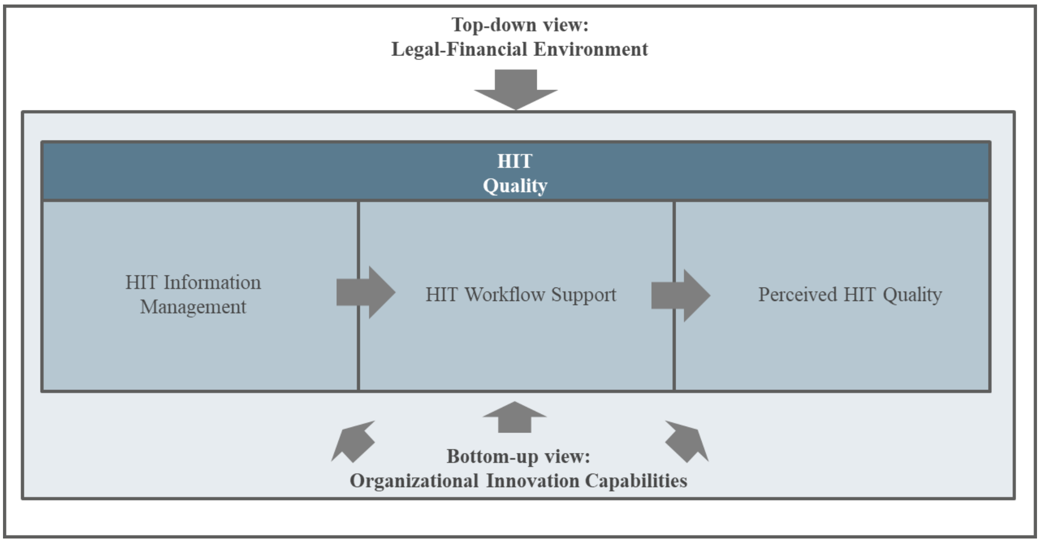

Figure 2: Conceptual Model.

Picking up on the domains of the TOE framework, it recognizes the interplay of organizational, environmental, and technical dimensions. The central focus thereby lies in the interaction between HIT quality and innovation capabilities of the organization. HIT quality comprises the quality of the implementation and support process (HIT Information Management), the quality of the technology supporting the clinical processes (HIT Workflow Support), and the perceived quality of this process support (perceived HIT quality). Crucially, it views HIT quality in the context of both a meso-level *bottom-up view* referring to the organizational environment and its resources, particularly concerning its capability to innovate as emphasized in the NASSS framework, but also recognizes a *top-down view* from the macro-level perspective that reflects the broader legal-financial environment within which the organization acts as is similarly suggested in the CFIR and the CAF.

The model also rests on the underlying assumption of a directional process of antecedents and consequences of HIT as was similarly conceptualized in studies by Greenhalgh et al. (2004), Leidner et al. (2010), and others. Thus, the organizational innovation capabilities are assumed to be antecedent to HIT quality and within the HIT quality domain, HIT information management is thought to precede HIT-based workflow support and the perceived HIT quality. The model ultimately seeks to help close a gap in the literature on the conceptual understanding of successfully digitizing care processes from an organizational point of view and thus serve as a framework for understanding corresponding intra-organizational dynamics related to innovation and quality of HIT. A better understanding of this might be helpful for healthcare managers to identify important determinants of HIT quality within their sphere of influence, for policymakers to gain a better understanding of how HIT can successfully be promoted on a large scale, and for educators to be aware of capabilities and mechanisms healthcare managers and policymakers should be trained for.

Text box 1 below summarizes the rationale behind the research questions and the proposal of the conceptual model. The following section goes on to detail how this approach was operationalized across the individual publications of this thesis.

Text box 1: Summative rationale of the thesis.

Problem Statement

- There is uncertainty about how high-quality HIT systems are adopted in health care practice which inhibits progress in clinical care. This can generally be researched on three different levels: the macro-, meso- and micro-level)
- On the macro-level, the legal-financial environment (e.g., in the form of incentive programs) can facilitate HIT usage, but only in limited terms.
- A wealth of research has already been directed at the micro-level (e.g., individuals' technology acceptance).
- At the meso-level, healthcare organizations (particularly hospitals) as sociotechnical entities are positioned at a critical bottleneck in translating HIT-based innovations into clinical care, i.e., translating product innovation from the outside into process innovation in the form of high-quality HIT systems.
- Very few reliable accounts exist on organizational facilitators of HIT other than mere structural characteristics. It can be assumed that particularly the capability to innovate, together with information management, plays a vital role in facilitating not only adoption but also HIT quality.
- Existing theoretical frameworks and previously published empirical models on related issues offer incomplete insights on this matter.

Research Gap

- There is no coherent conceptualization of what constitutes a) organizational innovation capabilities and b) the professionalism of information management. Consequently, there are no measurement frameworks available for research.
- Measures of HIT systems often are too simplistic, i.e., ignoring its complexity, the clinical processes it ought to support, and its perceived quality.
- There is no evidence on how organizational innovation capabilities influence HIT quality and what role information management and the legal-financial environment play in this relationship.

Objectives / Research Questions

- To find out what constitutes both innovation capabilities and professional information management and to develop corresponding measurement models.
- To research the relationship between innovation capabilities, the professionalism of information management, and other indicators of HIT quality, specifically the HIT workflow support and its perceived quality.

Approach to Address the Research Questions

- A conceptual model is proposed that structures the key domains of interest and serves as a basis for developing an empirical model.
- Publications 2-5 contain various steps for developing the required constructs and measurements in accordance with Research Question 1.
- Publications 1, 3, and 5 serve to analyze the relationships between domains (Research Question 2), with Publication 5 tying all strands together in an empirical model.

3. Methods

3.1. Overview and Research Design

Both research questions ought to be addressed by developing an empirical model for which the conceptual considerations above serve as a basis. Such empirical model development typically consists of two fundamental steps which directly correspond to the two research questions: (1) developing and refining construct measurements that capture the relevant domains and (2) investigating the associations between them (Bagozzi and Yi 2012). This also implies the application of a quantitative research design to test for construct validity and assertions as to the constructs' interrelationships. Since no pre-existing data is available to draw from that capture the relevant domains, suitable measurement tools had to be newly developed, which required conducting corresponding surveys.

Particularly the explorative development of constructs typically requires the usage of multiple surveys to explore the underlying dimensions and to end up with a sensible measurement scale that shows satisfactory convergent and discriminant validity (MacKenzie et al. 2011). Accordingly, an iterative approach across a total of 4 online surveys was used for this thesis (see next chapter for details), each preceded and accompanied by corresponding literature searches for the key domains of the conceptual model and their interrelationships. Despite the usage of multiple survey iterations over time and the analytical approach of this thesis, the overall research design qualifies as cross-sectional because each survey was analyzed separately.[5] However, results from preceding surveys informed subsequent questionnaire developments to refine scales and measurements. An experimental design was not warranted since, even if an exposure could have been clearly identified (innovation capabilities, for instance), neither the exposure nor the outcome could have been sensibly separated into distinct groups. Moreover, the author had no control over either the exposures or possible randomization.

Statistical Analyses

From a statistical viewpoint, the core methodology comprises a mixture of factor analysis techniques used for the construct developments and regression techniques for investigating associations. Both of these methodological strands are then integrated by applying structural equation modeling (SEM). SEM generally aims to determine the extent to which a proposed model in terms of a set of relations among underlying variables is supported by the observed data (Salkind 2010). It is a modeling technique that allows for examining the relationships between multiple variables (both latent and

[5] A longitudinal design would have been theoretically possible by, for instance, using the level of innovation capabilities in t1 to predict HIT quality in t2. However, this was not possible because combining data sets would have reduced the sample size too much, which would have corrupted the validity of the inferential statistics.

manifest) by combining statistical concepts that resemble confirmatory factor analysis, multiple regression, as well as mediation and moderation analysis in one set of equations.

Particularly the structural modeling is strongly driven by theoretical considerations as all structural paths in SEM have to be specified in advance. Corresponding hypotheses were derived from the theoretical frameworks, empirical studies, and from the findings that successively emerged within the various developmental steps in this thesis.

Structure Across the Publications

This research approach spans a total of five publications. They reflect a stepwise development of the model's components and an increasingly detailed exploration of the interrelationships as depicted in Figure 3. Herein, results of the previous publication are picked up in the succeeding ones to either iteratively specify measurement scales or to explore and refine the relationships between them. Details on these individual results and how exactly they eventually informed the subsequent steps are summarized in chapter 5.1.

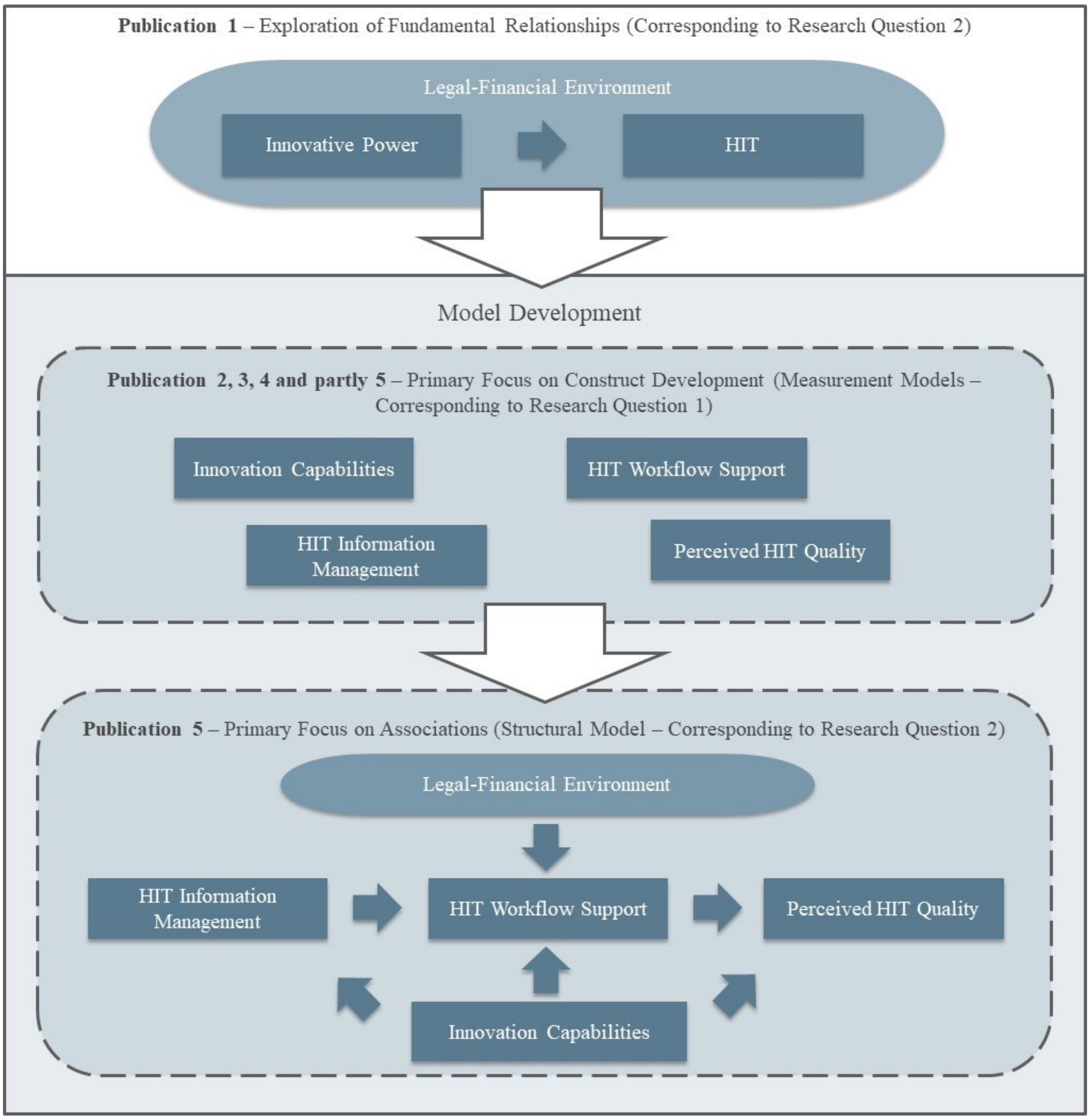

Figure 3: Integration of the publications in the context of the overall procedure.

The first publication served to explore the linkage between an organization's perceived ability to innovate ("innovative power[6]") and HIT adoption in general by employing a logistic and multiple regression analysis. It thereby also investigated the influence of the legal-financial environment on HIT adoption by including data from German and Austrian hospitals. The respective findings prompted a more detailed investigation of this relationship and the underlying constructs. Thus, the following three publications (2, 3, and 4) built upon the results by developing more detailed measures and multi-item scale sets – primarily using factor analytic approaches (Table 2).

Table 2: Publication Overview. RQ = Research Question.

	Primary research question of each publication	**Type of objective**		**Primary statistical method**
		Construct Development (relating to RQ 1)	Analysis of Associations (relating to RQ 2)	
Publication 1	Does the perceived innovative power of healthcare organizations influence HIT?		✓	Logistic & Multiple Linear Regression
Publication 2	What constitutes innovation capabilities from the perspective of hospital CIOs, and how can the construct be operationalized?	✓		Principal Component Analysis
Publication 3	How do different innovation capability constructs affect the perceived HIT quality from the perspective of clinical directors?	✓	✓	Exploratory Factor Analysis & Ordered Logit Model
Publication 4	What constitutes professional information management, and how can the construct be measured?	✓		Exploratory and Confirmatory Factor Analysis
Publication 5	How do innovation capabilities influence HIT quality in healthcare organizations?	✓	✓	Partial Least Squares Structural Equation Modelling

Publication 3 additionally tested for associations between innovation capabilities and the perceived HIT quality. The resulting scale sets and findings were then incorporated and extended upon in the final Publication 5 by means of applying SEM. As the structural relationships in SEM have to be specified in advance, the approach needs to be closely informed by theoretical considerations. The conceptual model in chapter 2.3 forms the basis for these considerations, which are translated into more differentiated specifications in Publication 5. Therefore, this publication can be understood as the centerpiece of the thesis as all topical strands from the previous four publications inform the final model proposed herein.

[6] After Publication 1, the terminology was changed from "innovative power" to "innovation capabilities" as the latter was considered to be a better description of what the construct conveys (see also chapter 5.4 for a discussion on the terminology use).

3.2. Data Sources

The development and refinement of the model components and the relationships between them comprised a stepwise approach throughout four surveys among hospitals as represented by their CIOs, nursing directors or medical directors between 2014 and 2017 (Table 3).

Data from Survey 1 (Hübner et al. 2015) provided the starting point for the analyses. Although the underlying item development and data collection preceded the start of this thesis and the author was not involved in it, the survey covered two essential topics for addressing the research questions. For one, it contained a set of 27 items measuring the availability of various IT functions, which corresponded to the items set of the OECD eHealth model survey from 2015 (OECD 2015). Furthermore, it measured the organizations' perceived ability to innovate, but only using a single scale. The survey was issued to nursing directors as hospital representatives in Austria and Germany and was utilized in Publication 1.

Table 3: Data Sources.

	Survey 1: IT-Report Healthcare 2015 (Hübner et al. 2015)	**Survey 2: SNIK Survey** (Jahn et al. 2016)	**Survey 3: IT-Report Healthcare 2020** (Hübner et al. 2020)	**Survey 4: IT-Report Healthcare 2018** (Hübner et al. 2018)
Utilized in Publication No.	1	2 & 4	3	4 & 5
Participants	Nursing Directors	Chief Information Officers	Nursing and Medical Directors	Chief Information Officers
Year of data collection	2014	2016	2017	2017
Countries included	AT, GER	GER	AT, CH, GER	AT, CH, GER
Topics covered:				
Innovation Capabilities	(✓)	✓	✓	✓
Information Management		✓		✓
HIT workflow support	(✓)		✓	✓
Perceived HIT quality			✓	✓
No. of recipients invited	1754	1284	2421	1499
No. of responses	543	164	403	251
Response rate	30.96%	12.77%	16.65%	16.74%
No. of items (utilized in this thesis)	33	20	25	188
Survey tool	Unipark	Unipark	Limesurvey	Limesurvey
Items developed by the author		✓	✓	✓
Data collected by the author			✓	✓

Multiple item scales for measuring innovation capabilities and HIT information management were first introduced with the SNIK survey – a survey focused on various information management issues from the CIOs perspective that was conducted in collaboration with the Institute for Medical Informatics, Statistics and Epidemiology at Leipzig University in 2016 (Jahn et al. 2016).[7]

[7] For this survey, the author developed the initial set of scales for measuring innovation capabilities together with JD Liebe. The item set measuring professional information management were developed together with

However, this thesis' most essential data sources were the two surveys conducted in 2017 for the IT Report Healthcare 2018 (Hübner et al. 2018) and 2020 (Hübner et al. 2020). The former, which addressed hospital CIOs, contained scales for all relevant subject domains. The development of these scales drew on the results and experiences from the previous two surveys as well as on works that preceded this thesis, especially on measuring HIT workflow support (Esdar et al. 2017; Liebe et al. 2015) (see chapter 3.3 below for details). Both surveys were issued to hospital representatives (CIOs, nursing and medical directors) in Austria, Switzerland, and Germany to factor in the legal-financial environment and enhance the generalizability of the results. The survey for the IT Report Healthcare 2018 served as the basis for the final empirical model (Publication 5). It was pretested by five hospital CIOs, ten researchers (comprising health IT experts, statisticians, and one psychologist), and one clinician to evaluate whether the question items were understandable and answerable and whether they were sufficiently precise to measure the various peculiarities of a health organization's information system.[8]

In a push to utilize an open software environment for collecting and processing the data for benchmarking purposes, as described by Weiß et al. (2017), Limesurvey was chosen as the tool for data collection for both surveys in 2017.[9] All surveys were closed, i.e., each participant had access to the surveys via a personal token issued via E-Mail, and all participants explicitly agreed for the data to be stored and used anonymously for research purposes.

In addition to the survey data, secondary data on demographic hospital information (bed count and ownership status) were used from the national quality reports from 2015 (Gemeinsamer Bundesausschuss). The respective dataset was matched with our survey data using the hospitals' institutional identifier (IK). The quality reports also contained the E-Mail addresses of the nursing and medical directors. However, contact information for the CIOs had to be searched by hand (through internet and telephone research) for both the SNIK survey and the IT Report Healthcare 2018. For the latter, CIO contact addresses were found for 2,324 hospitals, i.e., 92% of all 2,542 hospitals across Austria, Germany, and Switzerland at that time. All data were securely stored on servers of the University of Applied Sciences Osnabrück using a data warehouse that combines

JD Liebe, U Hübner, and the team from Leipzig University. JD Liebe collected the data with support provided by the author.

[8] In both surveys, the new item sets measuring innovation capabilities were developed by the author and reviewed by JD Liebe and U Hübner. The item set measuring HIT workflow support was based on previous surveys of the IT Report Healthcare (Hübner et al. 2014), but revised and supplemented (e.g. with items representing the admission workflow; see Appendix Table 2 of Publication 5) by the author (including revised response options), and subsequently reviewed by the entire Health Informatics Research Group at the University of Applied Sciences Osnabrück. The question items for measuring the perceived HIT quality were newly developed by the author and also reviewed by the research group. Information management issues were only covered in Survey 4 as the clinical directors from Survey 3 were not deemed qualified to answer them. The respective question items were based on the corresponding items from the previously conducted SNIK survey, but reviewed and slightly amended by the author and JD Liebe with support of the research group, particularly J Thye.

[9] Data collection, i.e., collecting and managing contact data, survey implementation in Limesurvey, testing, survey administration, and reminder management was done by the author for both surveys.

entity-attribute-value and data-vault models to integrate all data attributes from the surveys and quality report with one another (Rauch et al. 2017). SQL queries were used to export the data into the various statistical programs used in this thesis (R, SmartPLS and IBM SPSS) for conducting the analyses.

3.3. Data Analyses & Model Development

As outlined above, empirical model development requires two principal steps: the development of constructs and the analysis of the relationships between them. In terms of the statistical approach, developing constructs is achieved by applying factor analytic techniques. Herein, they are referred to under various terms that are conceptually very similar to one another (e.g., factors, latent variables, measurement models, and principal components). The analyses of relationships are conducted by employing various regression and related techniques, e.g., ordinary least squares regression, logistic regression, covariance analysis algorithms, partial least squares path modeling. In this thesis, both types of analyses are utilized in publications 1-4 and subsequently integrated with one another by employing partial least squares SEM (PLS-SEM) in Publication 5. In the context of PLS-SEM, the two steps of empirical model development find expression in the separation of the so-called measurement models (that measure constructs) and the structural model. Figure 4 conceptually depicts these two models with PLS-SEM annotations.

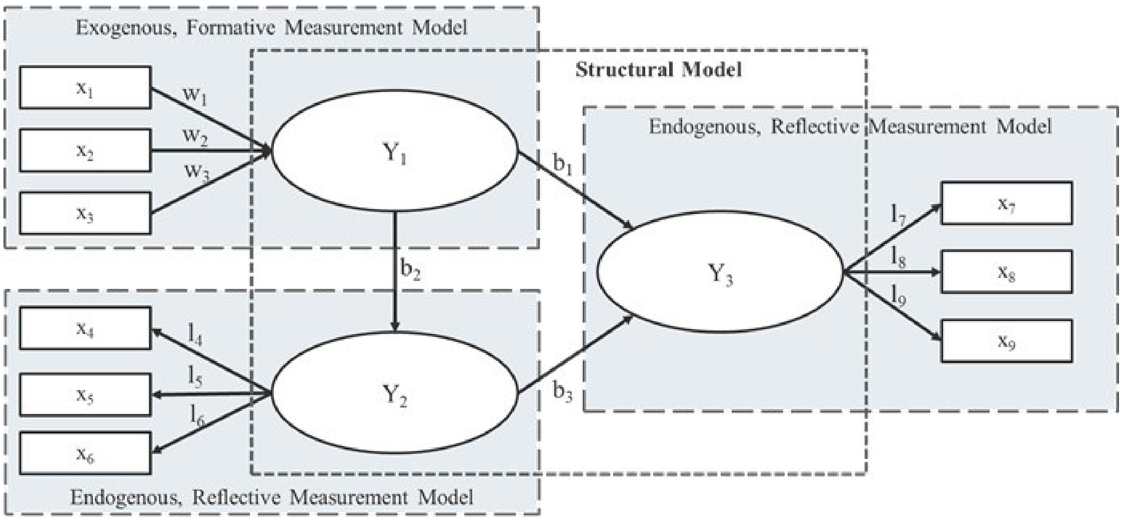

Figure 4: Structural Equation Model. x = raw indicators, w = other weights, l = outer loadings, Y = latent variable (construct), b = inner weight / path coefficient.

The structural model, sometimes more abstractly referred to as structural theory, shows how the constructs are related. The location and sequence of those relations are not estimated in an exploratory manner but instead based on "theory or the researcher's experience and accumulated knowledge" (Hair and Hult et al. 2017).[10]

[10] The theoretical assumptions that underlie the final structural model are depicted in detail in Table 2 of Publication 5.

Both principal steps, along with their related analyses, are detailed in the following two paragraphs with a focus on how they interlink across the different publications. More detailed statistical specifications can be drawn from the respective sections in the publications (chapter 4).

3.3.1. Construct and Scale Developments

The constructs and scales used in the final analysis in Publication 5 resulted from an iterative development work throughout the preceding publications of this thesis and from drawing on works conducted prior to this thesis (Esdar et al. 2017). Table 4 gives an overview of the operationalizations used to eventually represent the principal domains of interest, and Figure 5 depicts details on the iterations across the publications and surveys that led to this final set of constructs.

Table 4: Overview of the constructs (body) used to operationalize key domains from the conceptual model (header). Note that the legal-financial view is not included here as this was not represented in terms of a dedicated scale set but by including data from different countries.

HIT Quality			Innovation Capabilities
HIT Information Management	HIT Workflow Support	Perceived HIT Quality	
Professionalism of Information Management (PIM)	Workflow Composite Score (WCS) including technical descriptors and care processes	Perceived HIT Workflow Support (PHITS)	Innovation Capability: Top Management Team Support (IC TMT)
Clinical IT-Agents (CITA)		Overall Goodness of Information Provision (OGIP)	Innovation Capability of the IT Department (IC ITD)
			Organization-Wide Innovation Capability (IC OW)

Innovation Capabilities

Corresponding to the lack of consistent, integrated accounts of what can be regarded as a healthcare organization's capability to innovate and the absence of readily available scales that follow from that, the process of developing and refining this domain was subject to multiple iterations. As summarized in the left column in Figure 5, this approach spanned four out of the five publications.

Because the initial single-item scale in Publication 1 did not do sufficient justice to the multifaceted nature of this domain, the first multi-item scale set was proposed in Publication 2. The items used in this publication were derived from Patterson and colleagues' (Patterson et al. 2009) framework of people-relevant resources for innovation in organizations that distinguishes factors tied to the organization itself (external dimension) from intrapersonal factors (internal dimension). Pre-testing the inventory (undertaken by six hospital CIOs and eight health IT researchers) and subsequent principal component analysis resulted in three components: One that refers to the organization-wide innovation culture and top management team support with regard to HIT, and two referring to the intrapersonal factors. The latter, "personal" components were not further pursued because the primary subject of interest in this thesis was the organization as a whole rather than intrapersonal beliefs and attitudes of single actors within it.

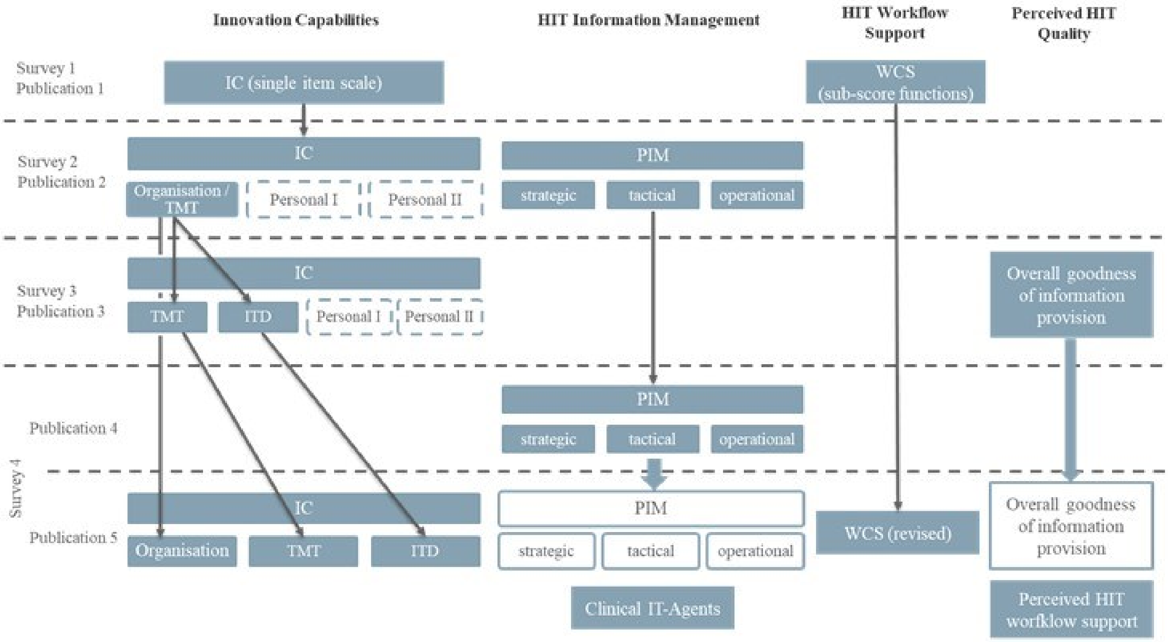

Figure 5: Development of the constructs and scales across the surveys and publications. The transparent constructs in the last column signal that corresponding scales were used unchanged in Publication 5 as compared to their original use in previous publications. Thin arrows indicate that amendments to the scales or constructs were made.

For Survey 3 and 4, additional literature on implementation frameworks, IT adoption, and factors of organizational innovation facilitation were reviewed across the disciplines a) implementation research, b) health informatics, c) information systems research, and d) management research (see sources in Table 5) in order to further expand on possible expressions of innovation capabilities. The search was focused on what latent factors and expressions of such factors were specifically hypothesized to facilitate innovational output (IT-related or otherwise) or denoted an innovation-friendly culture on the level of the organization as a whole, at the executive level, or with regard to the IT department. The themes and question items gathered from the search were then screened for suitability for the CIO or clinical directors to answer and for their relevance for innovating HIT specifically. Afterward, they were translated into statements that recipients could indicate their agreement with and subsequently pretested by another five hospital CIOs for Survey 2 and four clinical directors for Survey 3. The resulting items were then examined using exploratory factor analysis (in Publication 3 and 5). All factor analyses were conducted using the underlying variable approach, i.e., based on the matrix of polychoric correlation coefficients and the unweighted least squares estimation procedure with oblique rotation as is recommended for factor analysis with ordinal data (Forero et al. 2009; Holgado–Tello et al. 2010). Additionally, in the final SEM model, the measurement models reflecting the three innovation capability constructs were assessed for internal consistency using Cronbach's α and the Composite Reliability (CR). The outer variance inflation factors (VIF) were used to determine the collinearity issues among the indicators of a given construct. Convergent and discriminant validity was evaluated according to the height of the outer loadings, the average variance extracted (AVE), the Fornell-Larcker criterion, and the Heterotrait-Monotrait ratios (HTMT).

The final item set resulting from this process and utilized in Publication 5 is shown in Table 5, together with the studies they were derived from originally.[11]

Table 5: Question items for measuring organizational innovation capabilities.

	Item	Study
IC_TMT_1	"Our hospital has a well-defined future vision that is shared by the IT department."	Avgar et al. (2012), Faber et al. (2017), Ruvio et al. (2014)
IC_TMT_2	"Our executive board regularly seeks the exchange with the CIO."	Krotov (2015), Reinhard and Bigueti (2013)
IC_TMT_3	"As the CIO I have often been given positive feedback from the executive board for contributing innovative ideas."	Luthans et al. (2011), Leidner et al. (2010)
IC_TMT_4	"Our executive board explicitly calls for proposals of innovative eHealth solutions."	Patterson et al. (2009), Hurley and Hult (1998)
IC_TMT_5	"Our executive board actively promotes the initiation of new IT projects."	Howell and Boies (2004), Hurley and Hult (1998), Ruvio et al. (2014)
IC_TMT_6	"Our executive board regularly perceives IT as a mere expense factor." (reverse coded)	Leidner et al. (2010)
IC_ITD_1	"In the IT department, we regularly discuss new IT solutions with representatives of the specialist departments (clinical users)."	Liebe et al. (2016), Sadoughi et al. (2013)
IC_ITD_2	"In our team, creative ideas and suggestions for new IT applications are carefully listened to and discussed."	Jaén et al. (2010), Ruvio et al. (2014), Lynch et al. (2010)
IC_ITD_3	"Everyone in my team needs certain degrees of freedom in order to come up with the best possible solutions."	Jaén et al. (2010), Hurley and Hult (1998)
IC_ITD_4	"Employee creativity is a major driving force in our IT department."	Watts and Henderson (2006), Somech and Drach-Zahavy (2013), Lynch et al. (2010)
IC_ITD_5	"Our IT team has often shown a strong sense of cohesion."	Miron-spektor et al. (2011), Hülsheger et al. (2009)
IC_OW_1	"Our entire hospital shows great agility and flexibility when it comes to implementing and using new IT solutions."	Teece et al. (2016), Hurley and Hult (1998)
IC_OW_2	"In our hospital, new IT projects are openly communicated and discussed between all participants."	Ingebrigtsen et al. (2014), Hurley and Hult (1998), Gagnon et al. (2012)
IC_OW_3	"Our hospital is far too inflexible at all levels of hierarchy to use IT solutions in a meaningful way." (reverse coded)	Patterson et al. (2009), Gagnon et al. (2012)
IC_OW_4	"The responsiveness of our IT landscape to new requirements is excellent."	Ravichandran (2018), OECD (2018)

[11] Details on the origins of the question items for the domains in the following sections are not displayed here as they are described in the respective publications and since the items on the organizational innovation capabilities were the only measurements that were newly developed from the ground up for the purpose of this thesis.

IC_OW_5	“Our users and employees often have a fundamental aversion to IT.” (reverse coded)	Gagnon et al. (2012), Cresswell and Sheikh (2013)
Dropped due to poor suitability in the final factor solution (low outer loadings)	"Staff proposals for new IT solutions are actively encouraged at our hospital."	Sadoughi et al. (2013)
	"There is a transparent culture with regard to errors in our hospital."	Carroll and Edmondson (2002)
	"We have sufficient time, personnel, and financial resources available for new IT projects."	Damschroder et al. (2009), Sadoughi et al. (2013), Greenhalgh et al. (2017), Faber et al. (2017)
	"Our hospital shows a high willingness to take risks with regard to IT projects."	Lynch et al. (2010), Ruvio et al. (2014), Cresswell et al. (2017)

In the first innovation capability construct that refers to the top management team support, item IC_TMT_2 was the only one that was not part of the corresponding previous factor solution in Publication 2 and 3. The same applies to items IC_OW_4 and 5 in the construct, referring to the organization as a whole. Furthermore, none of the items referring to the innovation capabilities of the IT department (IC_ITD) were part of the previous factor solutions as they were only part of Survey 3. However, a corresponding factor referring to the IT department was identified in Publication 3, albeit with a different set of items as those data were collected from the perspective of clinical directors and not CIOs. Details on the scales are discussed in the respective publications and the discussion.

HIT Information Management

Similar to developing the innovation capability scales, a stepwise approach using factor analysis was used to develop the primary construct of this domain, the professionalism of information management (Figure 5).

In comparison, however, the conceptual underpinnings of PIM with regard to underlying constructs were more clearly delineated by the Japanese-German quality requirements framework of EHRs this thesis’ conceptual model draws on (Winter et al. 2017). As a result, the development process was somewhat more straightforward and consolidated in Publication 4. Herein, the model of MacKenzie et al. (2011) guided the scale development procedure. This included a two-tiered analytic approach with exploratory factor analysis (EFA) on data from Survey 2 and subsequent confirmatory factor analysis (CFA) on the corresponding data from Survey 4.

The resulting scale set was then transferred into the analysis conducted for Publication 5, thereby re-testing the psychometric structure resulting from Publication 4 using SEM: Three constructs that reflect 1) strategic, 2) tactical, and 3) operational IM activities. Details on the question items and their development can be found in Publication 4, chapter 4.4.3, and chapter 4.4.4.

In the structural model specified in Publication 5, PIM was integrated as a reflective higher-order model with PIM itself as the higher-order construct and its strategic, tactical, and operational sub-components as the lower-order constructs using the repeated indicator approach (Becker et al. 2012).

The three sub-components were not directly included in the structural model for several reasons. First, there was no indication from the literature or theoretical reason to assume that they would show different effects on the other endogenous variables in the model that were hypothesized to depend on PIM. Second, while the three sub-constructs exhibited sufficient discriminant validity according to the fit-indices from the CFA (CFI, TLI, RMSEA & SRMR) and the Fornell-Larcker criterion as well as the HTMT ratio in the SEM analysis, they still showed to be correlated with one another. Finally, forming a higher-order construct allowed for reducing the complexity of the final model, thereby favoring a more parsimonious model solution.

To complement the information management activities captured by PIM, the presence of formally appointed clinical IT agents (CITA) was additionally considered to be a part of the HIT information management domain in Publication 5. While clinical IT agents are not directly tied to the IT department and thus not accounted for in the PIM item set, they are still widely considered to be a strong predictive force for HIT to be successfully adopted (Potts et al. 2011; Sligo et al. 2017; Gagnon et al. 2012).

HIT Workflow Support

This domain was specified to be represented by the Workflow Composite Score only. The original score was developed by Liebe et al. (2015) on the theoretical assumption of there being four descriptors (data and information, IT functions, integration and distribution) required for HIT to be able to support various clinical workflows (ward rounds, pre-surgery, post-surgery, and discharge) and thereby enabling effective clinical information logistics in these workflows, i.e., the information systems' ability to provide the right information for the right person, at the right time and in the right quality.

For Publication 1, only a subset of the items underlying the WCS was used: Those representing the descriptor IT functions. This was done because the questionnaire from Survey 1 was directed at nursing directors who were not deemed appropriate to answer the complete set of the question items required for calculating the entire WCS, particularly those items aimed at rather specific technical issues such as technologies used for data integration or syntactic interoperability standards. Survey 2, despite being addressed to CIOs, did not include the WCS item set either because it was exclusively focused on information management issues. Thus, the complete set of question items for the WCS was only included in Survey 4 and used for Publication 5. Herein, the original score was partly revised and extended. The most important extension was that the *admission* was included along with corresponding items reflecting HIT-based support in this workflow, in addition to the four above-mentioned workflows. Figure 6 displays the basic structure of the final WCS version used in Publication 5.

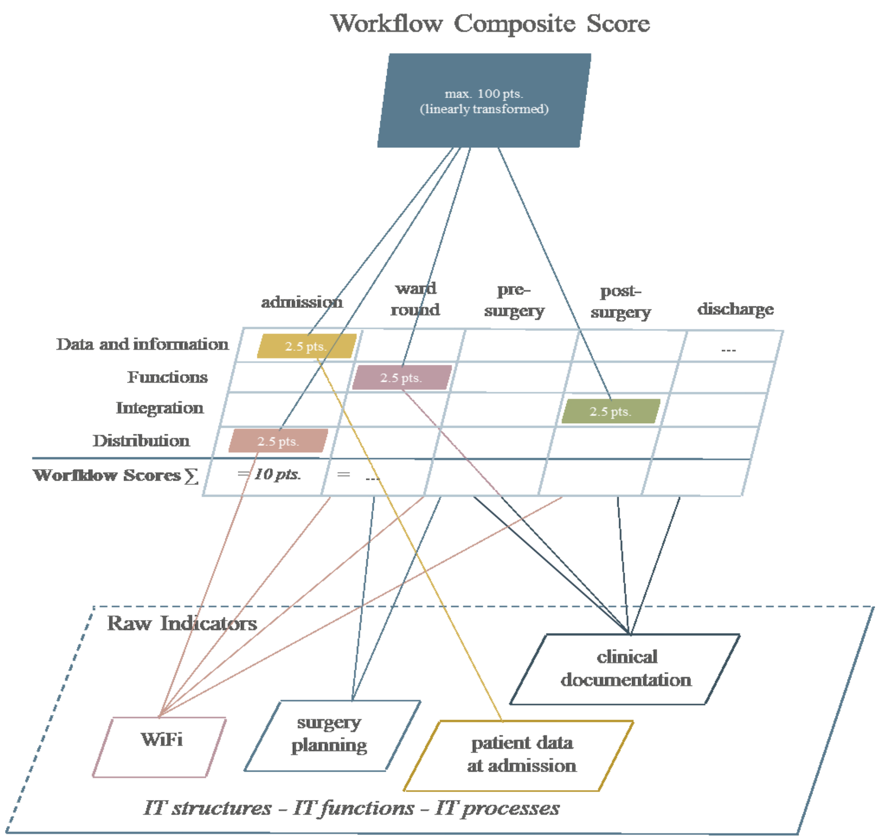

Figure 6: Schematic structure of the Workflow Composite Score.

Furthermore, question items based on recent technological developments and a preceding validation study (Esdar et al. 2017) were added across the different workflows and descriptors. This was done, however, without changing its original structural design. Additionally, a revised weighting scheme for the underlying items based on the analytic hierarchy process (AHP) technique (Saaty 1988) with pairwise indicator comparisons was applied based on in-group discussions among four of the authors of Publication 5. The template for applying this weighting scheme and the corresponding algorithms are described in detail by Straede and Thye (2013). The purpose of the weighting was to emphasize the importance of specific features in certain workflows – for example, mobile access to patient data (via smartphone, tablets, or computer on wheels) was deemed more important for ward rounds than for pre-surgery processes. The resulting weights, the 146 underlying question items, their assignment to the descriptors and workflows, and a short description of how the WCS was calculated, are displayed in Appendix Table 2 of Publication 5. Because of its structural makeup and the weighting scheme, the WCS is designed to be an indicator that captures the raw availability of HIT components and contextualizes these in the care processes, thus representing HIT workflow support. Since this was a largely predefined composite score, it was formally included in the model as a single item construct.

Perceived HIT Quality

As described in chapter 2.1.3.33 above, the concept of HIT quality needs to not only recognize the technical manifestations of HIT but also requires the incorporation of a subjective assessment of its perceived quality – particularly with regard to how well the ideals inherent to the concept of clinical information logistics can be realized. Perceived HIT quality can, in principle, be evaluated from a managerial as well as a clinical end-user perspective. The managerial view refers to the overall appraisal of the IT workflow support by the CIO or clinical directors and thus is rooted in their deep understanding of the IT infrastructure and its applications. In contrast, the perspective of the clinical end-users reflects how they perceive the IT workflow support from the angle of usability, practicability, and alignment with daily clinical work in their various organizational units. This thesis emphasized the managerial perspective to be consistent and reduce heterogeneity. The added value of the end-user perspective is further elaborated in the discussion. Perceived HIT quality was, therefore, primarily captured by using only a single item scale that asked for the organization's general ability to provide the right information, at the right time, at the right place, for the right persons, and in the right quality to support patient care processes form the viewpoint of CIOs and clinical directors in Survey 3 and 4, respectively. After pretesting, this was deemed an appropriate proxy of the organization's overall HIT quality. Therefore, the scale was used as a dependent variable in both Publication 3 and 5.[12]

In Survey 4, CIOs were additionally asked to grade the HIT workflow support (referred to as "perceived HIT workflow support – PHITS") in all five aforementioned clinical care processes separately, and the resulting indicators were included in a reflective measurement model in Publication 5. Thus, the model includes a scale that conceptually bridges the WCS with the overall goodness of information provision (OGIP) in that it focuses specifically on the perceived IT support concerning the same workflows that were used for the WCS. OGIP, in contrast, was more broadly phrased as it referenced the organization's ability to provide the right data in care processes in general.

3.3.2. Analysis of Relationships and Structural Model Development

In the first phase of the structural model development, associations between parts of the abovementioned constructs and related country differences were explored in Publication 1 and 3. In Publication 1, two types of regression analysis were conducted. First, a logistic regression model was used to test for the "top-down" influence of the legal-financial environment on the availability of the various IT functions that make up the corresponding descriptor in the WCS by using the country as the binary outcome (Austria or Germany), and the WCS items as predictors. Second, in the complementary bottom-up view that focused on the organizational level, multiple linear regression models were used to examine the relationship between the organizations' innovative power and the WCS descriptor score "IT functions". Both the top-down and the bottom-up view were later taken into account in the final model in Publication 5 by including the effect of the legal-financial

[12] Note that this variable was simply referred to as "clinical information logistics" in Publication 3 and as "overall goodness of information provision" in Publication 5 in order to apply a more consistent and simplified terminology within the latter publication.

environment (this time also including Switzerland) as well as the effect of innovation capabilities on HIT workflow support as measured by the WCS.

In Publication 3, an ordered logit model was used to test for associations between the innovation capabilities, now operationalized by multi-item scales aggregated by calculating factor scores, and the ordinal scaled OGIP variable (referred to as clinical information logistics in that publication). Again, results from that model were then used to inform the structural model specification in Publication 5 (see chapter 5.1 for details on how exactly).

All regression models controlled for structural hospital characteristics that are typically considered to be associated with HIT adoption and success, namely the hospitals' size in terms of bed count, the health system affiliation, ownership status, and the existence of a surgery room.[13]

The structural model specification in Publication 5 rested on a set of hypotheses that were partly derived from the results in Publication 1 and 3 but was also driven by findings and suggestions from the literature for the various relationships between the constructs (see Table 4 in Publication 5 for details) as well as from the theoretical considerations reflected in the conceptual model. The previously developed constructs and their hypothesized interrelationships were then fitted into a structural equation model.

The model parameter estimation was done using the partial least squares SEM algorithm (PLS-SEM). PLS-SEM is a relatively young statistical methodology that gained popularity in management and information systems research during roughly the last decade (Hair et al. 2017a), but also increasingly finds application in medical informatics and other health-related sciences (Avkiran 2018). It emerged as a supplement to the traditional, covariance-based SEM (CB-SEM) approach which has a more confirmatory character (Hair and Hult et al. 2017). It is particularly advantageous in that it (1) does not make assumptions about the data distribution (non-parametric approach), (2) allows to include interaction effects, (3) can handle ordinal and dichotomous data, and (4) is more efficient in handling model complexity (Hair et al. 2011). But more importantly, PLS-SEM optimizes for accurate predictions by aiming at minimizing the residual variance in the constructs indicators instead of optimizing for parameter fit by minimizing the residual covariance between indicators (which is what the common factor model used in CB-SEM aims for). As a result, PLS-SEM is considered more appropriate when the research goal is to predict key target constructs and identify important “driver” constructs, rather than testing established theories that use widely consented measurement models (Hair and Matthews et al. 2017). Since there was no specific theory available that would have allowed for a predetermined model specification to test in a confirmatory fashion, PLS-SEM was chosen to be the appropriate statistical approach for this thesis. Furthermore, PLS-SEM met the formal requirements of the data sources with regard to its tolerance of the use of categorical data in the measurement models, and as it allows the inclusion of reflective measurement models (i.e., manifest indicators *reflect* the latent construct), formative measurement models (i.e., manifest indicators *form*

[13] The latter two confounders were included in Publication 3 only.

the latent construct) as well as single item scales without identification problems (Hair and Hult et al. 2017). Given the sample size of 232, it was also ensured that the calculated model estimates exhibit sufficient levels of statistical power when using PLS over CB-SEM (Hair and Hult et al. 2017), as it has shown to be superior in this regard (Reinartz et al. 2009).

The basic formal assumption for estimating the measurement models in PLS-SEM is conceptually comparable to common factor models, expressed as

$$x = lY + e \qquad \textit{Eq. 1}$$

Herein, x is the observed indicator variable, Y represents the latent variable, l the factor loading, indicating the strength of the association between x and Y, and e is the error term, i.e., representing the random measurement error.

However, the computation of the model parameter differs from CB-SEM in that PLS-SEM uses composite models, i.e., the algorithm calculates values for the latent variables (comparable to factor scores in common factor models) for every empirical observation. To this end, the latent variables are estimated as linear combinations of their underlying empirical indicators such that the resulting composites capture most of the underlying indicators variance that is useful for predicting the indicators of the dependent, latent variables in the structural model (Sarstedt et al. 2017). Accordingly, running the PLS-SEM algorithm always requires specifying a structural model with at least two latent variables, i.e., one latent independent and one latent dependent variable.

In its most basic form, the corresponding algorithm is divided into two stages (Henseler 2012). The first stage consists of an iterative estimation of the latent variable scores as well as inner and outer weights[14] using four steps:

1. Outer approximation of the latent variable scores:

   $$Y_{jn} := \sum_{k_j} \widetilde{w}_{k_j} x_{k_j n} \qquad \textit{Eq. 2}$$

   The latent variable scores (Y_{jn}) are defined to be calculated as the assigned indicators ($x_{k_j n}$) weighted ($\widetilde{w}_{k_j}$) sum where $x_{k_j n}$ represents the raw data for indicator k (k = 1,...,K) of latent variable j (j = 1,...,J) and observation n (n = 1,...,N). In the initial iteration, equal weights are set for all indicators of a given latent variable (usually $\widetilde{w}_{k_j} = 1$). The weights are then updated after each iteration using the results from Step 4.

2. Estimation of the inner weights:

   $$b_{i_j} = \begin{cases} cov\left(Y_j; Y_i\right) \\ 0 \end{cases} \qquad \textit{Eq. 3}$$

   Step 2 uses the initial latent variable scores from the initialization of the algorithm to determine the inner weights b_{i_j} for the structural model, i.e., between adjacent latent

[14] In PLS-SEM, inner weights refer to the strength of the relationship between latent variables, outer weights to the strength of the relationship between (observed) indicators and the associated latent variable. Outer weights are equivalent to factor loadings in reflective models, and inner weights form the basis for the path coefficients, which can be interpreted as standardized regression coefficients.

variables Y_j (i.e., the dependent ones) and Y_i (i.e., the independent ones). If latent variables are not specified to be associated with one another in the structural model, the inner weight is fixed to 0. There are different approaches to this estimation. Displayed above is the factor weighting scheme that uses the covariance between the adjacent latent variables to estimate the inner weights. Other common methods are the path weighting scheme and the centroid scheme. However, Lohmöller (1989) showed that the choice of the scheme has little bearing on the final results.

3. Inner approximation of the latent variable scores:

   $\tilde{Y}_j := \sum_i b_{i_j} Y_i$ *Eq. 4*

   In addition to the outer approximation in step 1, inner proxies ($\tilde{Y}_j$) for all latent variables are computed in step 3 as linear combinations of their adjacent latent variables scores Y_i and the previously determined inner weights (b_{i_j}) obtained in step 2.

4. Estimation of the outer weights, solve for:

   Mode A: $\tilde{Y}_{jn} = \sum_{k_j} \tilde{w}_{k_j} x_{k_j n} + d_{jn}$ *Eq. 5*

   Mode B: $x_{k_j n} = \tilde{w}_{k_j} \tilde{Y}_{jn} + e_{k_j n}$ *Eq. 6*

   In this last step, new outer weights are estimated using either the bivariate correlation between each indicator and the latent variable (i.e., correlation weights; Mode A) or by regressing each latent variable on its underlying indicators (i.e., regression weights; Mode B). Mode A is used for measurement models that are specified to be reflective, and Mode B for formative measurement models. In the estimation equations, d_{jn} represents the unique variance (error term) from a bivariate regression and $e_{k_j n}$ the error term from a multiple regression. The resulting outer weights ($\tilde{w}_{k_j}$) are then used as an updated input for the next iteration. All four steps are repeated iteratively until the changes in the sum of the outer weights drop below a defined threshold (i.e., the stop criterion).

In the second stage, the converged estimates of the outer weight resulting from stage 1 are used in a series of ordinary least squares regressions to calculate the final model parameters, including the latent variable scores, the indirect, direct, and total path coefficients as well as R^2 values for the endogenous latent variables (Lohmöller 1989).

The PLS-SEM analysis in this thesis closely followed the current methodological guidelines and recommendations (Hair et al. 2018; Hair and Hult et al. 2017): The parameter estimation was done using the path weighting scheme with a stop criterion of 10^{-7}. In order to test the hypotheses in the structural model, the inner VIF values for collinearity were examined first. Then, path coefficients and mediation effects were evaluated based on the direct, total, and indirect effects with P values and 95% confidence intervals obtained from 10,000 bootstrap replications. Moreover, the f^2 effect sizes were calculated to assess whether a specific exogenous construct substantially contributed to an

endogenous latent variable's R^2 value (Cohen 2013). Besides the R^2 values for the endogenous latent variables, blindfolding was used to obtain the cross-validated redundancy measure Stone-Geisser's Q^2 (omitting every 7^{th} observation for the estimation) in order to determine the predictive relevance of the exogenous constructs for an endogenous latent variable under consideration.
Even though reliable goodness of fit statistics are not yet established for PLS modeling and their application is conceptually questionable (Henseler et al. 2014), model fit was assessed according to the standardized root mean residual (SRMR). Finally, the model was checked for distortions by unobserved heterogeneity in the structural model using finite mixture PLS segmentation (FIMIX-PLS) (Hair et al. 2016).

To summarize, the analysis of the relationships between the constructs of interest (Research Question 2) were addressed in two phases: In the first phase (Publication 1 & 3), only selected parts of the conceptual model were analyzed by conducting various regression techniques depending on the data's scale levels (multiple linear, binary and ordinal logistic regression). In the second phase (Publication 5), the resulting associations from phase 1 were integrated and extended by using structural equation modeling to develop the final model covering all parts of the conceptual model.

4. Results

4.1. **Publication 1:** Innovative Power of Health Care Organisations Affects IT Adoption: A bi-National Health IT Benchmark Comparing Austria and Germany

Published as: Hüsers, J., Hübner, U., **Esdar, M.**, Ammenwerth, E., Hackl, W. O., Naumann, L., & Liebe, J. D. (2017). Innovative power of health care organisations affects IT adoption: A bi-national health IT benchmark comparing Austria and Germany. *Journal of Medical Systems*, 41(2), 33.

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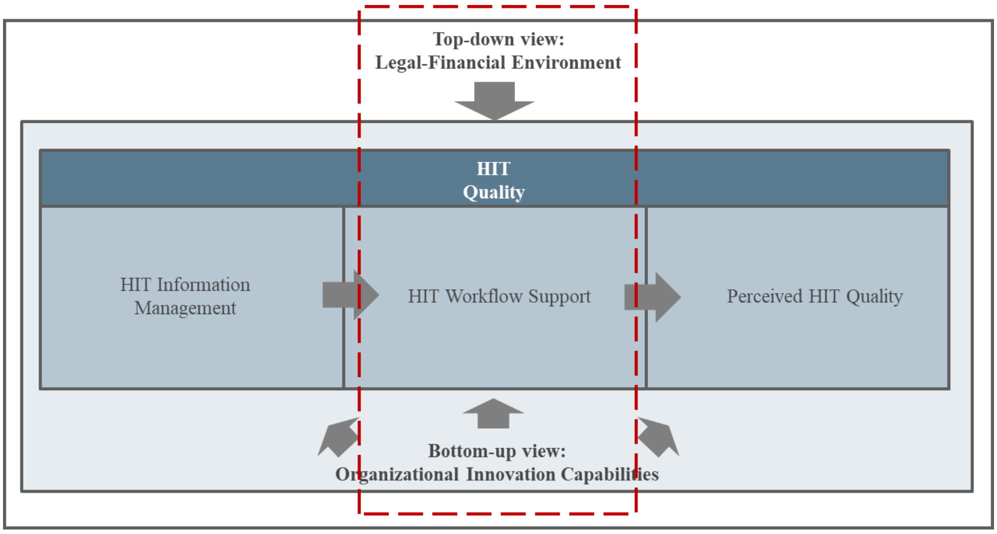
5-Year Impact Factor: 3.95

Ranked A – 9th out of 35 Health IT Journals (Serenko et al. 2017)

Topics covered of the conceptual model



Abstract. Multinational health IT benchmarks foster cross-country learning and have been employed at various levels, e.g. OECD and Nordic countries. A bi-national benchmark study conducted in 2007 revealed a significantly higher adoption of health IT in Austria compared to Germany, two countries with comparable healthcare systems. We now investigated whether these differences still persisted. We further studied whether these differences were associated with hospital intrinsic factors, i.e. the innovative power of the organisation and hospital demographics. We thus performed a survey to measure the "perceived IT availability" and the "innovative power of the hospital" of 464 German and 70 Austrian hospitals. The survey was based on a questionnaire with 52 items and was given to the directors of nursing in 2013/2014. Our findings confirmed a significantly greater IT availability in Austria than in Germany. This was visible in the aggregated IT adoption composite score "IT function" as well as in the IT adoption for the individual functions "nursing documentation" (OR =

5.98), "intensive care unit (ICU) documentation" (OR = 2.49), "medication administration documentation" (OR = 2.48), "electronic archive" (OR = 2.27) and "medication" (OR = 2.16). "Innovative power" was the strongest factor to explain the variance of the composite score "IT function". It was effective in hospitals of both countries but significantly more effective in Austria than in Germany. "Hospital size" and "hospital system affiliation" were also significantly associated with the composite score "IT function", but they did not differ between the countries. These findings can be partly associated with the national characteristics. Indicators point to a more favourable financial situation in Austrian hospitals; we thus argue that Austrian hospitals may possess a larger degree of financial freedom to be innovative and to act accordingly. This study is the first to empirically demonstrate the effect of "innovative power" in hospitals on health IT adoption in a bi-national health IT benchmark. We recommend directly including the financial situation into future regression models. On a political level, measures to stimulate the "innovative power" of hospitals should be considered to increase the digitalisation of healthcare.

Keywords. Austria, Germany, Health IT, IT adoption, IT benchmarking, eHealth

4.1.1. Introduction

International health IT benchmarking initiatives

Multinational health IT benchmarks have become a common instrument to measure IT indicators that give an account of the readiness for health IT in a country and to stimulate cross-country learning [1]. The OECD eHealth model survey is a methodological approach to define relevant indicators in terms of availability and use of a broad range of systems and functionalities in different health care settings from the perspective of different stakeholders [2]. Parts of the OECD model survey formed the foundation of the Survey of the European Commission where hospitals from 30 countries responded to questions of the availability and use of systems, health information exchange, IT infrastructure, context and governance variables [3].

Cross-country learning that draws on benchmark facts allows politicians to find out whether the eHealth strategy in their country meets the initial expectations, to learn from best practice examples and to align the eHealth strategy accordingly [4]. With the many differences in healthcare systems around the globe that potentially affect the adoption of eHealth, benchmarking among countries with a similar healthcare context seems promising to identify eHealth specific facilitators and inhibitors [5]. In 2012, the Nordic countries therefore launched an initiative to benchmark the availability, use and usability of eHealth systems across their countries [6]. Another example of health IT benchmarks in similar healthcare system environments was the comparison between Germany and Austria [7], which was conducted in 2007 and published in 2010.

Against this background we decided to repeat the Austrian German health IT benchmark using relevant OECD indicators. Knowing that both healthcare systems are shaped to a large degree by national regulations [8, 9], laws have the potential to exert a strong influence on the general health IT climate and on the monetary conditions of the health care organisation [10, 11]. In addition, other factors with a potential impact on health IT adoption, in particular the perceived innovative power of the organisation could make the difference between adopting and non-adopting organisations. Some case studies hint at the importance of organisational innovativeness [12, 13]. Finally, there are other facilitators and inhibitors on the level of the hospital demographics known from the literature, which need to be taken care of for adjustment, first and foremost "size" of the organisation [14, 15], ownership [16], teaching status [14, 17] and system affiliation [18].

Healthcare systems in Germany and Austria

Germany and Austria both have an insurance-based healthcare system with the majority of the population insured in the statutory health insurance (Table 1). Whereas Germany has higher expenditures per capita, life expectancy at birth is marginally lower. Austria furthermore shows a higher physician- and nurse-to-bed ratio with regard to acute care facilities, which hints at a better staffed acute care system. Austria also shows a shorter average length of stay.

Table 1. Selected Indicators describing the healthcare systems in Austria (AUT) and Germany (GER). All indicators show data from the year 2013. Total Population come from the OECD Population statistics [19]. All other indicators are from the OECD Health at Glan

Indicator	AUT	GER
Total population in Mio.	8.5	80.6
Public and private health expenditure per capita in US $	4,553.1	4,818.9
Life expectancy at birth in years	81.2	80.9
Hospital beds per 1000 population	7.7	8.3
Percentage of population in statutory or primary private health insurance in %	99.9	99.8
Average length of stay in days	6.5	7.7
Physicians-to-bed ratio (Full Time Equivalent)	0.33	0.23
Nurse-to-bed ratio (Full Time Equivalent)	0.90	0.61
Spending of the statutory health insurance per hospital bed in Euro	161,482	127,482

Research framework

In order to benchmark Austria and Germany with regard to health IT, we propose a research framework, which describes the environment and potential forces in this field (Figure 1). The benchmark object in our study was the availability of IT functions in the hospital information systems. The availability was judged by the clinical stakeholders as the experts, who are familiar with the IT functions and IT systems that shape the clinical processes. We thus speak of "perceived technical availability", which can differ from the "technical availability" as seen through the eyes of a chief information officer [21] and from the actual "use" of these functions.

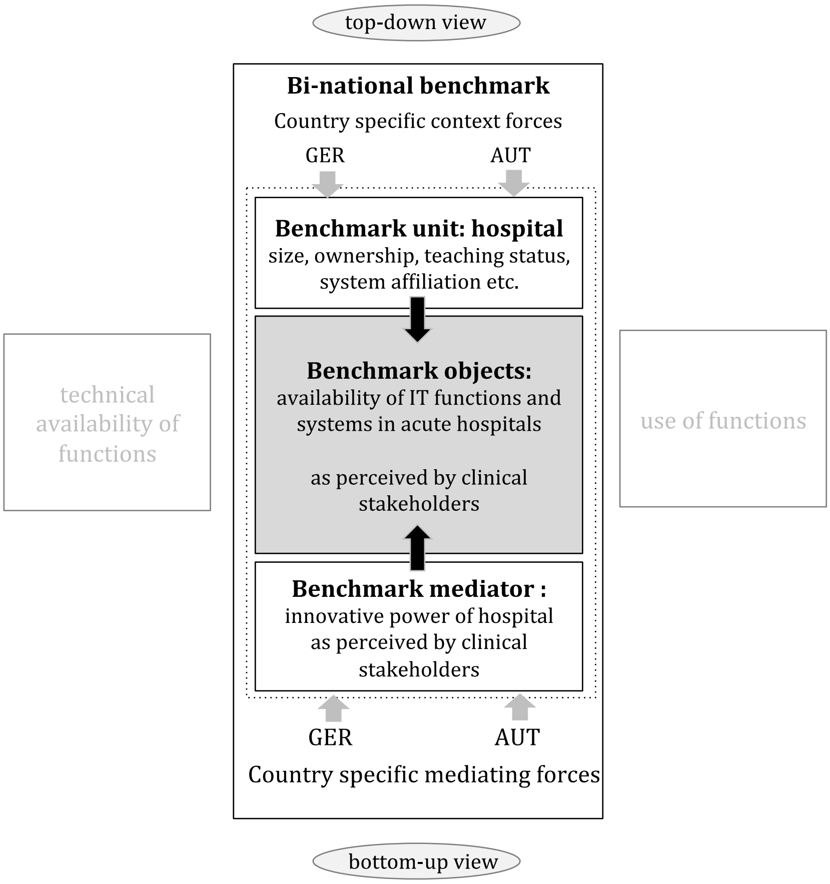


Figure 1. Research Framework of the eHealth Benchmark between Germany (GER) and Austria (AUT): variables in black font were observed in this study, black arrows mark the integration of the variables into the regression analysis, light grey arrows mark environmental forces that could affect the results but were not included into the regression analysis.

In our framework, we assume that IT adoption of hospitals is exposed to two major potential forces: The top-down force "country specific forces, in particular the legal-financial environment" and the bottom-up force "innovative power of the organisation". This research framework also integrates existing knowledge about hospital demographics exerting a potential influence on IT adoption as discussed above. The framework draws on existing models, particularly on the socio-technical-material framework [22], in which the material environment, e.g. laws, financing schemes and other forces, that cannot be changed easily, was integrated.

This framework allows the following research questions to be derived:

1. Do German and Austrian hospitals differ with regard to their "perceived technical availability" of IT functions?
2. Do demographic factors of the organisation play any role to explain possible differences?
3. Does perceived "innovative power" of an organisation contribute to the understanding of potential differences between the two countries?

Country specific context forces will be used to discuss the results rather than to phrase research questions.

4.1.2. Methods

Study design and measurement instrument

We conducted an observational cross-sectional study in acute hospitals in Austria and Germany. We hereby chose directors of nursing as representatives of clinical stakeholders to answer the questions. Due to their dual role as experts in the clinical field and as board members or as high-ranking executives they oversee the area of interest. Furthermore, they represent the largest group of healthcare professionals in a hospital, who are exposed to IT systems in their daily work.

IT adoption was operationalised by measuring the "perceived technical availability" of 27 IT functions that were taken from the OECD eHealth model survey and previous surveys within the framework of IT Report Healthcare [23, 24]. These functions covered the six clusters: "documentation", "order entry and results reporting", "decision support", "patient safety", and "supply chain functions" and "interface functions". The implementation status of each of these IT functions had to be rated on a 4-point Likert scale (1 = "no implementation planned", 2 = "implementation started/resources provided", 3 = "implemented in at least one unit but not in all", 4 = "implemented in all units").

In addition, the hospital demographics "country", "location", "size", "ownership", "system affiliation", "teaching status" and "surgery available" were included into the questionnaire. "Innovative power" of the organization was rated on a 10-point scale with 1 denoting no power and 10 the highest possible power. The entire questionnaire[15] is shown in Appendix Table 4.

Data management and statistical analysis

One thousand seven hundred fifty four email addresses of German and 169 of Austrian directors of nursing in hospitals could be identified by Internet research. They represented 96.1% percent of the German acute hospitals[16] and 95.5% of the Austrian ones. The questionnaire was made available to them between November 2013 and February 2014 [23] utilising the online survey tool Unipark (http://www.unipark.com).

All data were analysed using R (Version 3.2.1). Statistical significance was set at alpha = 0.05. To account for multiple testing, p-values were Bonferroni adjusted. In order to describe the two samples, we tested for differences with regard to the demographic variables using logistic regression analyses with the criterion country (Austria as reference). The samples were also contrasted with the population in each country regarding the "size" of the hospital (see Appendix Table 5).

In order to compare both countries, we used a sub-score within the Workflow Composite Score (WCS) [26], an aggregated score, which measures the IT potential of hospitals to support clinical workflows. WCS provides four descriptors which are represented by sub-scores: (1) data and

[15] The entire questionnaire comprised 52 questions. Only results related to the research questions are presented in this paper.

[16] The German population of hospitals was constitued by those hospitals that had to deliver a quality report.

information, (2) IT function[17], (3) integration of IT functions and (4) distribution of data and information. These sub-scores, which are reflective of points given to IT features that relate to the particular descriptor, are expressed as normalised sum values [26]. In this study these values could range from 0 to 100 points.

To evaluate the IT adoption of both countries we utilised the sub-score "IT function". It is a highly reliable score (split half reliability r = 0.89) that integrates the 27 IT functions addressed in this survey [26]. The sub-score “IT function” served as criterion in a stepwise forward multiple linear regression analysis, into which “country”, the demographics variables and the variable “innovative power” were entered as predictors. The final model was tested for non-multi-collinearity, homoscedasticity and normal distribution of the residuals. The significant predictors of this model were used in subsequent logistic regressions to test the country differences on the level of the 27 individual IT functions. To this end, the implementation status of the 27 IT functions was dichotomised, which were then analysed as criterion in univariate logistic regressions with “country” as predictor and adjusting for demographic variables.

4.1.3. Results

Sample

A total of 464 German and 70 Austrian directors of nursing took part in the survey, which corresponded with a response rate of 26.5% in Germany and 41.4% in Austria. Hospitals of all “size” categories and federal states participated in both countries. We compared the sample data to all population measures that were made available by the responsible federal offices (portion of for-profit hospitals, bed-size and teaching status in Germany and portion of for-profit hospitals as well as the bed-size in Austria). Significance testing revealed no significant differences between the sample and the population in both countries (see Appendix Table 5). Additionally, we compared the sample data of both countries: There were no country specific differences with regard to “size”, “system affiliation”, “teaching status” and availability of a “surgery theatre” (Table 2). Only “ownership” turned out to be significantly different with an odds ratio of 2.24 (95% CI 1.31–3.78), i.e. a 2.24 greater chance to find a for-profit hospital participating in the survey in Austria compared to Germany (Table 2).

[17] This descriptor was originally called “function“[26]. For the sake of clarity, we changed it to “IT function”.

Table 2. Summary of hospitals demographics (95% CI in brackets) and the results of univariate logistic regression analyses for hospital demographics (predictor) and country (criterion) of the sample.

Sample	Overall	GER	AUT	Odds Ratio (95% CI)	p
Hospital size (number of beds)	299.32 [n=515]	299.52 [n=445]	298.04 [n=70]	1.000 (0.999-1.001)	0.969
Percentage of hospitals affiliated to a multi-hospital system	49.90% [n=487]	48.47% [n=425]	59.68% [n=62]	1.378 (0.943-2.035)	0.101
Percentage of hospitals with surgery	69.66% [n=534]	70.47% [n=464]	64.29% [n=70]	0.754 (0.448-1.294)	0.295
Percentage of for profit hospitals	27.31% [n=509]	24.94% [n=441]	42.65% [n=68]	2.238 (1.313-3.781)	0.003**
Percentage of teaching hospitals	53.38% [n=444]	52.85% [n=403]	58.54% [n=41]	1.259 (0.660-2.451)	0.488

***$p < 0.001$, ** $p < 0.01$, * $p < 0.05$

IT adoption: "Perceived technical availability"

Figure 2 shows the frequency distribution of the adoption[18] of the 27 IT functions in the two countries. This descriptive approach revealed nine IT functions with nearly equally distributed adoption rates (difference less than five percentage points). Eleven IT functions had higher adoption rates (> five percentage points) in Austria whereas seven functions showed higher adoption rates in Germany. The highest difference in favour of Austria was found for "nursing documentation" ($\Delta = 35.8$ percentage points), the highest difference in favour of Germany for "identification of samples" ($\Delta = 23.0$ percentage points).

[18] These frequency distributions relate to the data without "no response" answers, which had been coded as missing values. These frequencies therefore differ from the ones published in the IT Report Healthcare [23], where the distributions of all responses are shown.

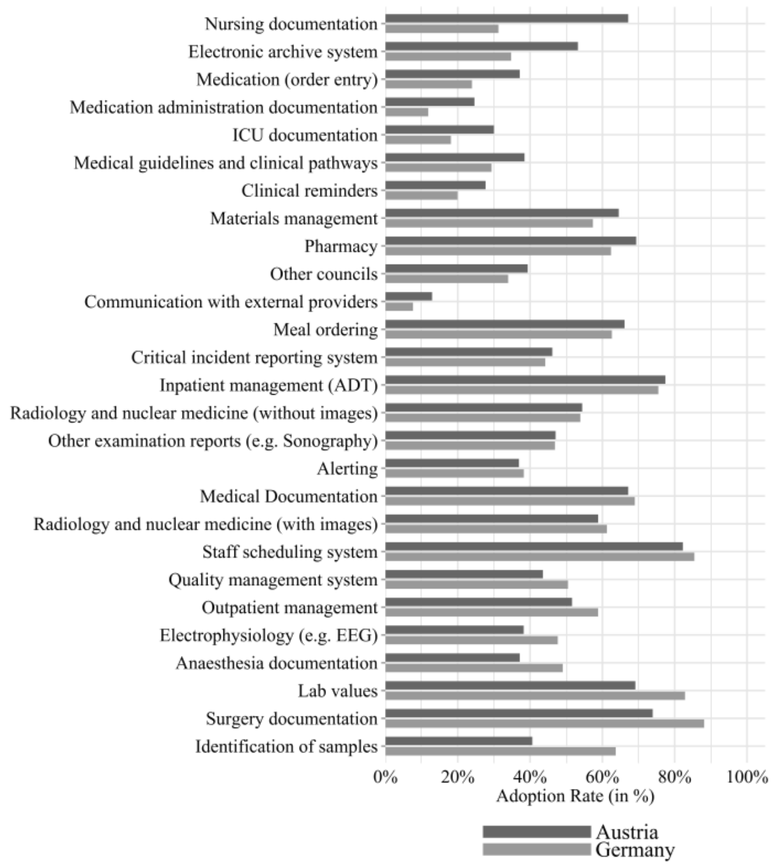


Figure 2. Adoption rates (implemented in at least on unit) for 27 IT functions sorted by size of difference with the largest positive difference between Austria and Germany at the top.

The aggregated WCS sub-score "IT function", which provided an integrated view on all IT functions, yielded an arithmetic mean of 57.9 (SD = 18.8, n = 70) for Austrian hospitals and of 52.3 (SD = 12.6, n = 464) for German hospitals. The two countries differed significantly with regard to this score (p = 0.027). This indicated a higher adoption level of IT functions in Austrian hospitals compared to German ones.

In order to explain the variance of this score a stepwise forward multiple linear regression analysis was performed. "Innovative power" had the strongest effect with the highest beta coefficient (p = 0.000) on the aggregated score. Furthermore, the variance of the "IT function" sub-score could be also explained by the demographic variables "hospital size" (p = 0.000) and "hospital system affiliation" (p = 0.015). These results indicated that larger hospitals and those hospitals belonging to a multihospital system had higher "IT function" values. The final model with the four significant predictors could account for 42.8% of the total variance in "IT function" (Table 3).

Table 3. Final multiple linear regression model resulting from stepwise forward selection with „IT function sub-score" as criterion (all models see Appendix Table 6).

Independent Variables	Beta-Weight (p-Value)
Intercept	0.000 (0.000)***
Innovative power	0.572 (0.000)***
Hospital size	0.288 (0.000)***
Country (Austria as reference)	0.151 (0.001)***
System affiliation (hospital in a multihospital affiliation as reference)	0.099 (0.025)*
R^2	0.433
Adj. R^2	0.428
F-statistic:	77.61
Degrees of freedom (df)	4 and 406
p-value:	0.000
n	411

****p < 0.001,** p < 0.01,** * p < 0.05

The effect of "innovative power" on the aggregated WCS sub-score "IT function" was similar for both countries: more innovative hospitals had higher scores than less innovative ones as shown in the two univariate linear regression analyses (Figure 3). However, Austrian hospitals had significantly higher innovation values ($\bar{x}$ = 6.9, SD = 2.1; n = 60) than German hospitals ($\bar{x}$ = 5.9, SD = 2.1; n = 409). A univariate logistic regression analysis with country as criterion resulted in a significant OR value of 1.25 (95% CI 1.09–1.44).

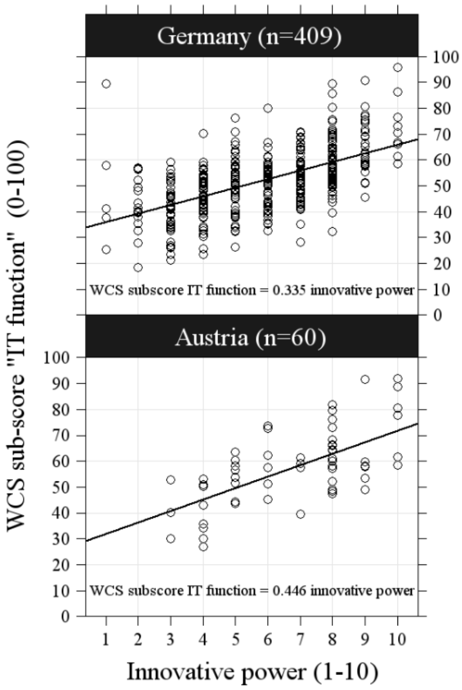


Figure 3. Scatterplot "innovative power" of the organisation perceived by the Directors of Nursing versus WCS sub-score "IT function" for both countries.

IT adoption: adjusted "perceived technical availability" for individual IT functions

Based on the knowledge that "innovative power", "hospital size" and "hospital system affiliation" could significantly explain the variance of the aggregated "IT function" sub-score (WCS), the computation of the OR values of the 27 individual functions were adjusted for the influence of these two demographic variables. Knowing that the two samples differed significantly with regard to hospital "ownership" this variable was included as third demographic factor for the adjustments.

The adjustment for demographic variables (all values of the adjustment see Appendix Table 7) led to a significant difference between the countries for "identification of samples" (OR = 0.39), showing that Germany had a higher IT adoption. Concerning adoption rates with higher values in Austria, the stage 1 adjustment resulted in five IT functions with significantly higher perceived availability, i.e.

- "nursing documentation" (OR = 5.98).
- "Intensive care unit (ICU) documentation" (OR = 2.49) and
- "medication administration documentation" (OR = 2.48),
- "electronic archive" (OR = 2.27),
- "medication" (OR = 2.16),

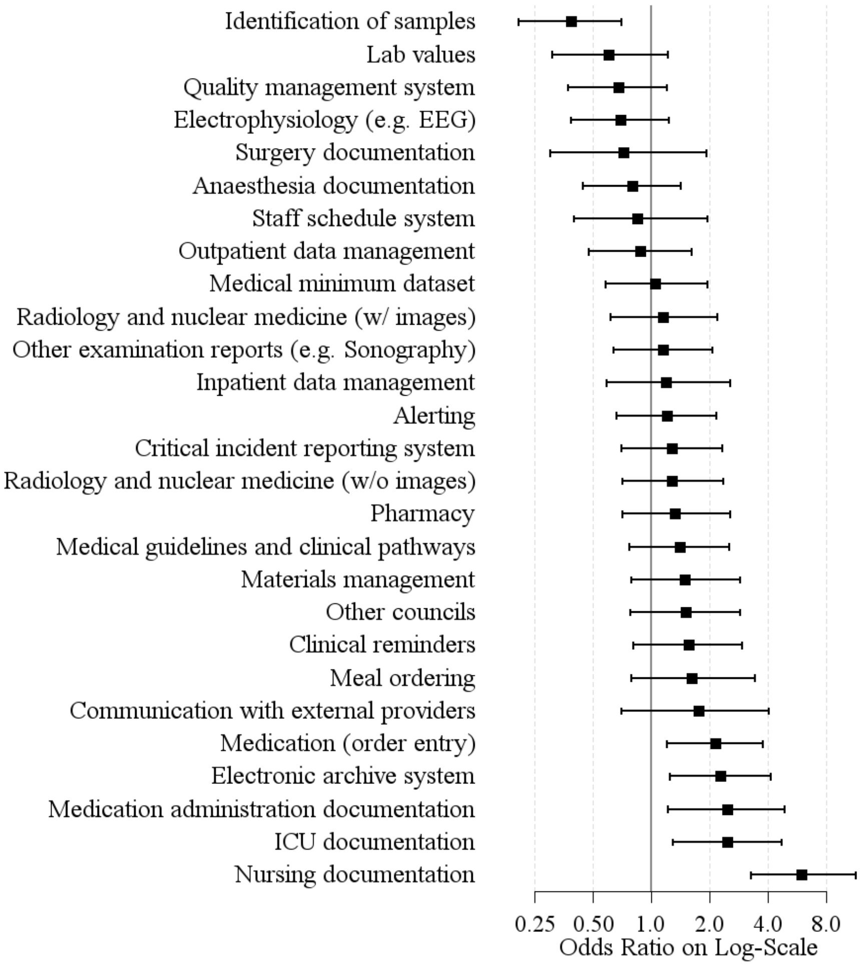


Figure 4. Adjusted OR values and 95% CI for demographic variables. Austria served as reference category in the logistic regression: OR > 1 indicates a greater chance that an IT function is implemented in Austrian hospitals than in German ones. For example, having implemented a nursing documentation system was 5.98 times more likely in Austria than in Germany.

4.1.4. Discussion

Sample and research questions

This study is based on a large sample of hospitals in Austria and Germany with a good response rate. A wide coverage of different hospitals from different regions in both countries and of different size classes participated.

There is a higher "perceived technical availability" of IT in Austrian hospitals compared to German hospitals. "Nursing documentation", "ICU documentation", "medication administration documentation", "electronic archive" and "medication" show a significantly greater availability in Austrian hospitals. In comparison, only one IT function, i.e. "identification of samples", was more often available in Germany.

These results partly resemble the findings of the 2007 study, which was published in 2010 [7]. At that time "nursing documentation" and "electronic archive" showed a significantly higher availability in Austria than in Germany. This indicates that the differences between both countries persisted over the years. Our findings of the significantly higher composite sub-score "IT function" in Austria than Germany also comply with a comparable sub-score (AUT = 0.653 versus GER = 0.502), which was developed in the context of the European Hospital survey [25].

Hospital "size", i.e. the number of beds, and "system affiliation", i.e. whether the hospital was working on its own or in a multihospital system, were found to significantly influence the variation of the sub-score "IT function" but could not explain the difference between the two countries. The association between hospital demographics and IT adoption matches other findings with regard to "size" and "system affiliation" [14,15,18] but contradicts the literature with regard to the effect of "ownership" and "teaching status". The correlation between the latter two variables and hospital "size" may explain this result [14]. In both countries, teaching hospitals and not for profit hospitals tend to belong to the group of larger hospitals.

"Innovative power" of the organisation as perceived by the directors of nursing exerted a forceful effect on the variation of the WCS sub-score "IT function", which was not only significant but yielded the highest beta coefficient in the model. "Innovative power" worked uniformly in both countries with regard to fostering IT adoption, but was significantly higher in Austria than in Germany. Thus the overall potential impact of "innovation power" was stronger in Austria than in Germany.

Research framework

The research framework, which underlays this study, assumed two main forces: the bottom-up force "innovative power" of the organisation and top-down forces, in particular the legal-financial environment. At first glance, the influence of "innovative power" seems trivial or tautological. However, we contend that the strength of this factor was not predictable, even though we expected some positive correlation with IT adoption. Our findings affirm statements which emphasise the important role of "innovative power" and the "organisational culture" [12,26] but did not demonstrate it empirically. Innovation always entails some sort of risk to be associated with the implementation of an innovation [27]. Organisations with strong innovative power often venture forth on unchartered territory also at the costs of failure.

"Innovative power" could therefore be also associated with the top-down acting context factor legal-financial environment. In Germany, shortcomings in the reimbursement of investment costs within the G-DRG system are discussed as a strong inhibitor of innovative changes with mid- or long-term return of investment [28]. IT often needs time to unfold its potential and contribute to a positive cost-benefit ratio because of a complex implementation and integration process [29,30]. Unlike Austria, Germany shows an ongoing trend to shorten the length of stay (LOS). This difference may explain a higher pressure to act in Germany [31] and to curb costs, e.g. cutting nursing staff (see lower nurse-to-bed ratio in Germany in Tab. 1) instead of investing in new technology. Comparing the spending of the statutory health insurance per hospital bed in both countries also reveals a more favourable situation in Austria than in Germany (161,482 Euro in Austria versus 127,482 Euro in Germany in Tab. 1). Assuming similar cost structures, these figures point to the fact that there is more money in the health care system in Austria than in Germany.

The top-down force legislation had been discussed in the 2007 study to account for the higher adoption rates of "nursing documentation" in Austrian hospitals. Austria had passed a law, the Austrian Healthcare and Nursing Act [32], already in 1997 that stipulates the documentation of the full nursing process including the nursing diagnoses [7]. It was argued that it took some time before this law got manifested in corresponding IT adoption rates of "nursing documentation" systems. The effects of this law can still be seen. In Germany, the Nursing Complex Intervention Score (German: Pflegekomplexmaßnahmen Score PKMS) of the Hospital Financing Reform Law of 2009 [33] could potentially stimulate the uptake of "nursing documentation" but became effective in 2012 only. This circumstance may have made it difficult to measure its effect in particular given a slow acceptance of the PKMS.

Legislation seems to be most effective if it stipulates health IT and at the same time helps building enough free space to let health IT emerge or to give direct incentives for health IT adoption such as the Meaningful Use Program in the United States of America [34].

Limitations

The limitations of this study are related to the research design as an observational cross-sectional study that does not allow any causal relations to be derived. We assume that "innovative power" comes prior to IT adoption and thus may influence adoption behaviour. However, it could also be the other way round. Because organisations had implemented novel IT functions they felt they were innovative. Even more complex, feeling innovative and behaving innovative may be intertwined in a self-reinforcing process [35], i.e. because an organisation judges its "innovative power" as high, it adopts innovative technology and because it has adopted innovative technology it judges its "innovative power" as high.

Apart from "innovative power", other factors may have a potential influence on health IT adoption, e.g. "management of the IT implementation process" and "user support" [36], commitment of the top management team [13,27] and participation of clinical end users [37]. They should be considered in the future. In addition, "innovative power" itself needs further clarification in particular facilitators and inhibitors, e.g. factors acting behind the scenes such as IT governance and centralisation [38].

Cross-sectional studies are prone to the self-selection bias. There are statistical techniques such as the propensity score that aim to remediate this bias [39]. We did not employ any of these methods because we did not find significant differences between the samples and the corresponding populations with regard to a selected number of variables. Equally, we did not have access to specific variables that might differentiate between responders and non-responders and thus could be entered into propensity analyses.

Another limitation arises from marking the questionnaire only available to directors of nursing. Even though they represent the largest user group of health IT in hospitals, this study lacks the perspective of other medical professions such as physicians or therapists that would complement the users viewpoint in hospitals.

4.1.5. Conclusions

This study is the first to empirically demonstrate the effect of "innovative power" in hospitals pursuing a regression approach in a bi-national health IT benchmark. We recommend including the financial situation of healthcare organisations into future regression models. On a political level, measures to stimulate the "innovative power" of hospitals should be considered to increase the digitalisation of healthcare.

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4.2. **Publication 2:** Exploring Innovation Capabilities of Hospital CIOs: An Empirical Assessment

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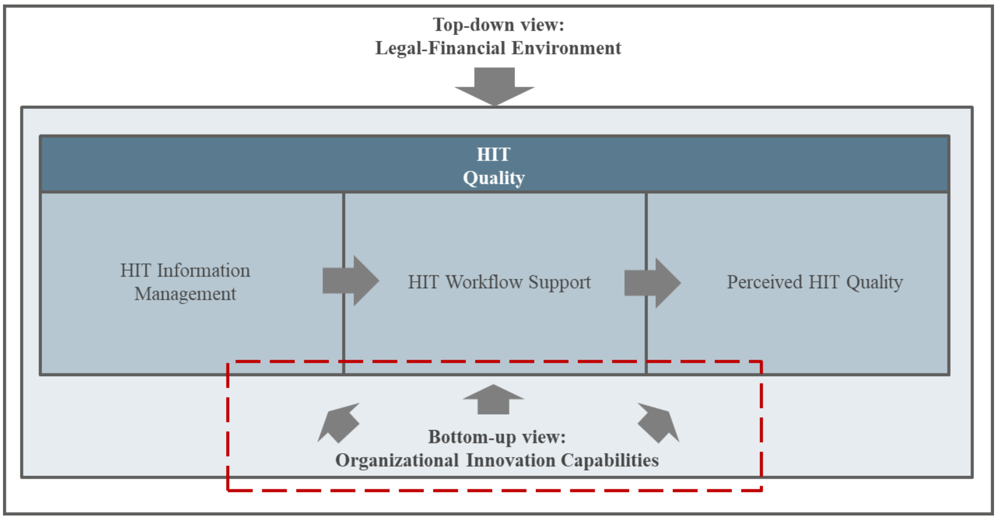

Abstract. Hospital CIOs play a central role in the adoption of innovative health IT. Until now, it remained unclear which particular conditions constitute their capability to innovate in terms of intrapersonal as well as organisational factors. An inventory of 20 items was developed to capture these conditions and examined by analysing data obtained from 164 German hospital CIOs. Principal component analysis resulted in three internally consistent components that constitute large portions of the CIOs innovation capability: organisational innovation culture, entrepreneurship personality and openness towards users. Results were used to build composite indicators that allow further evaluations.

Keywords. Innovation capability, Innovation management, composite indicator, hospital CIOs

4.2.1. Introduction

A rich body of studies agrees that Chief Information Officers (CIOs) occupy a central position in visioning, guiding and implementing IT based innovations [1,2]. These innovations can generally be defined as changes of products and processes that result from the adoption of IT and are new to the given organisation [3]. In the hospital context, IT innovations mostly fall under the category of process innovations (e.g. the widespread implementation of a new clinical decision support system or telemedicine solutions) that lead to significant changes of the related workflows or process outcomes [4].

Even though empirical investigations could substantiate the critical role of CIOs to foster IT innovations in the industrial sector [e.g. 5], there is no scientific evidence about the innovation capability of CIOs in healthcare, particularly in hospitals. In fact, there are reasons to assume, that hospital CIOs innovation attempts might be challenged by specific social and organisational circumstances [6]. Although medical decision-making processes cannot be entirely automated, as they require complex medical knowledge as well as the clinician's individual experience [7], the respective workflows can still be significantly improved by providing accurate data and information. The goal hereby is to seamlessly integrate the information flow into the clinician's work practice and particularly support advanced clinical processes. This phenomenon is described by the information logistics construct [8] which matches one of the criteria for innovation proposed by Hübner [4]. At this point, the innovational capability of the CIO often makes the difference between IT success and failure as they not only have to be very considerate with the clinician's expectations, autonomy and the peculiarities of the medical workflows, but also act in an environment that is characterised by financial restrictions [2]. Health information technology (HIT) is known to be frequently perceived as a mere cost factor by the executive board and therefore often lacks adequate support [9]. Specific innovation capabilities of CIOs may therefore be constituted by their ability to mediate between highly skilled professions and to act as an enabler within a potentially restrictive organisational environment. This is also referred to as intrapreneurship [10].

Up to date, empirical studies about hospital CIOs mainly focus on questions related to their structural power (position, reporting level etc.) [11] and on how these factors correlate with given CIO roles or decision types [9]. Whereas these approaches are meaningful in themselves, they often neglect the underlying personality (e.g. the CIOs views and attitudes) and environmental patterns (e.g. the executive board's attitude towards IT). Our goal, therefore, was to 1) shed light in what constitutes innovation capabilities of hospital CIOs both in terms of intrapersonal as well as organisational factors and 2) determine how the innovation capability construct can be operationalised.

4.2.2. Methods

Original scales were developed based on Patterson and colleagues' [3] framework of people relevant resources for innovation in organisations that distinguishes environmental factors tied to the workplace (external dimension) and intrapersonal factors (internal dimension). We initially operationalised each domain by 40 items on different types of scales. Pre-testing the inventory (undertaken by 6 hospital CIOs and 8 health IT researchers) resulted in a final inventory of 20 Items, 10 for each domain measured by Likert scales. Data were collected between February and April 2016 via an online survey. We obtained 164 valid responses from a total of 1284 contacted German CIOs (response rate 12.77%).

In order to 1) explore underlying patterns of our data, 2) reduce the inventory to a set of variables that describe innovation capability, 3) test the discriminant and convergent validity and reliability (using Cronbach's alpha) as well as to 4) develop an empirically founded composite indicator, we performed principal component analysis (PCA) [12]. Following strong recommendations of the methodological literature [13], we applied the underlying variable (UV) approach using polychoric correlation coefficients since all included variables were measured on ordinal scales. Applicability of the correlation matrix was evaluated based on the Kaiser-Meyer-Olkin (KMO) criterion and Bartlett's test of sphericity. Components were extracted if their eigenvalue exceeded 1, if all components explained at least 50% of the total variance and based on consulting the scree plot. We allowed the extracted components to correlate by using oblique rotation since we did not assume them to be entirely distinct from each other. To obtain a set of meaningful and discriminant items, we gradually removed items that could not be fitted in the component structure (i.e. showed heavy cross loadings or component loadings < .5 across different model solutions). The final solution was tested for reliability and then interpreted in a group discussion of eight experts (comprising health IT scientists, statisticians, management researchers and a psychologist).

Component loadings and eigenvalues were used to deploy a weighting scheme adapted from the Organisation for Economic Co-operation and Development (OECD) [14] in order to build a composite indicator for each component and for the full inventory that accentuates the components and corrects for statistically overlapping information.

4.2.3. Results

According to a KMO measure of .73 and a significant result of Bartlett's test of sphericity our data proved to be suited for PCA. Moreover, the sample to variable ratio was 13:1 and therefore was above recommended minimum ratios which typically range between 5:1 to 10:1 [15]. In the course of reducing the inventory, we attained a final set of 13 items that were ideally reflected in a solution comprising 3 components (Table 1) explaining 51% of the total variance. Interrelations between the components remained low with correlation coefficients less than .15.

Table 1. Component loading matrix. Loading below .3 are left blank.

Item	Component		
	1	2	3
"Our executive board actively promotes innovative IT solutions."	.82		
"Our hospital has a well-defined future vision that is also being pursued by the IT department."	.74		
"Our hospital shows great flexibility when it comes to employing innovative IT."	.74		

"Our hospital is way too rigid on all levels of hierarchy to employ IT in a strategically meaningful fashion." (reverse coded)	.70		
"IT is perceived as a mere expense factor by our executive board way too often" (reverse coded)	.68		
"Our IT department is only able to provide highly valuable services if every employee consistently covers an unchanged range of tasks" (reverse coded)		.68	
"My work mainly consists of realising the wishes and ideas of other people." (reverse coded)		.66	
"As the person in charge of IT, I first of all rely on well-established IT solutions." (reverse coded)		.57	
"My work motivation would be significantly higher if I was paid adequately to my knowledge and skills." (reverse coded)		.52	
"A CIO has to first of all take care of technical and not people issues." (reverse coded)			.76
"It is very important to me to have great knowledge of the clinical processes in our hospital."			.63
"Listening and giving advice are the core competencies in my role as a CIO."			.62
"It is very important to us to incorporate the different clinical end users in our IT projects."			.56

The full scale showed acceptable reliability in terms of internal consistency with α = .71. Similarly, component 1 showed good internal consistency (α = .78) whereas components 2 (α = .64) and 3 (α = .52) showed lower but acceptable reliability values given the relatively low number of associated items. The components were interpreted as "organisational innovation culture" (component 1), "entrepreneurship personality" (component 2) and "openness towards users" (component 3).

Table 2. Descriptive statistics of the developed composite indicators (n = 164).

Composite Indicator	Mean	SD	Range	Skewness	Kurtosis
Full inventory	55.86	12.29	59.67	.15	-.34
Component 1	53.33	20.54	100	-.18	-.04
Component 2	42.25	15.23	86.66	.17	.41
Component 3	74.98	14.27	67.06	-.35	.06

Table 2 displays the distributional properties of the calculated composite indicators that were built using the data driven weighting scheme referred to above. Each indicator was scaled to range between 0 (complete disagreement with all related statements) and 100 (complete agreement with all related statements).

4.2.4. Discussion

The importance of the CIOs' innovation capability increases with the growing potentials and diffusion of HIT. Hitherto it remained unclear which particular conditions constitute these capabilities (research question 1) and how these conditions can be operationalised (research question 2).

Results of the PCA and subsequent score development indicated two essential findings with regard to question 1. At first, it confirmed a clear empirical distinction of the external dimension opposed to internal (intrapersonal) aspects, as all items of component 1 were originally intended to measure the environmental dimension. In contrast to interpreting this component as the general organisational environment it can be specified as organisational innovation culture and support from the executive board. This aligns well with existing theoretical knowledge pointing out the importance of top management support [16] that gives HIT based innovations the required flexibility [17], active financial promotion, and guiding principles and vision [2] for innovative HIT to prosper. All these aspects seem to be indicative of a coherent dimension describing a fundamentally positive attitude towards innovative IT within the organisation. The second finding reveals that the previously assumed "internal dimension" has to be broken down into two separate dimensions, i.e. into "entrepreneurship personality" and "openness towards users". "Entrepreneurship personality" is a composition of traits that embraces intrinsic motivation and self-determination, a mindset of internal freedom to deviate from established paths and to take risks. This is a clear contrast to tayloristic attitudes. "Openness towards users" is a trait that is closely related with "involvement of users" and "participation" of users, which is a well-known success factor in systems engineering [5] and in innovation alike [8]. Our initial thoughts on CIOs' specific requirement of closely incorporating the clinician's interests when striving for HIT innovations now show an empirical manifestation in this component.

With regard to question 2, the analysis led to a full set of 13 items measuring three different dimensions of innovation capability. Whereas internal consistency measures where satisfying for component 1, reliability measures for component 2 and 3 were marginally acceptable. Greater precision and redundancy in these domains are desirable in further investigations. However, the full set of items showed an acceptable internal consistency with $\alpha = .71$. It was reduced on the grounds of the PCA results. Although this is a common methodical approach [12], it potentially threatens the construct's integrity since a few aspects were removed which might have been retained if they were captured with greater redundancy (i.e. more questions). It therefore is reasonable to assume that there might be more to innovation capability beyond our model's dimensions. Another limitation arises from the modest response rate of 12.77% that might have caused a non-response bias in our sample. The results can therefore only be generalised with caution and require further validation in different samples.

The resulting composite indicator is normally distributed around a mean of 56 points (out of 100). Thus, innovation capability seems to be moderately advanced in German hospitals with clear potential for development. It is most notably that component 3 "openness towards users" showed significantly higher values with $\bar{x} = 75$ whereas component 2 "entrepreneurship personality" only showed an average score of 42. Many hospital CIOs apparently understand the importance of participation and user focus but are still surprisingly prone to a work approach that does not create much space for self-determination and deviation from established paths. The actual impact of the composite indicator and its subscales still needs to be tested against innovation performance measures to further assess their validity and to determine which particular aspects most strongly drive HIT innovations. This study provides a fundamental toolset to do so.

4.2.5. Conclusion

This study gives insight into the constituents of the construct innovation capability of CIOs and defines a set of items to operationalise this construct. In contrast to previous findings, we not only distinguish between internal and environmental factors, but clearly denote them specifying the dimensions unique to hospital CIOs. We hereby lay the foundation of a psychometric inventory to measure innovation capability.

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4.3. **Publication 3:** Determinants of Clinical Information Logistics: Tracing Socio-Organisational Factors and Country Differences from the Perspective of Clinical Directors

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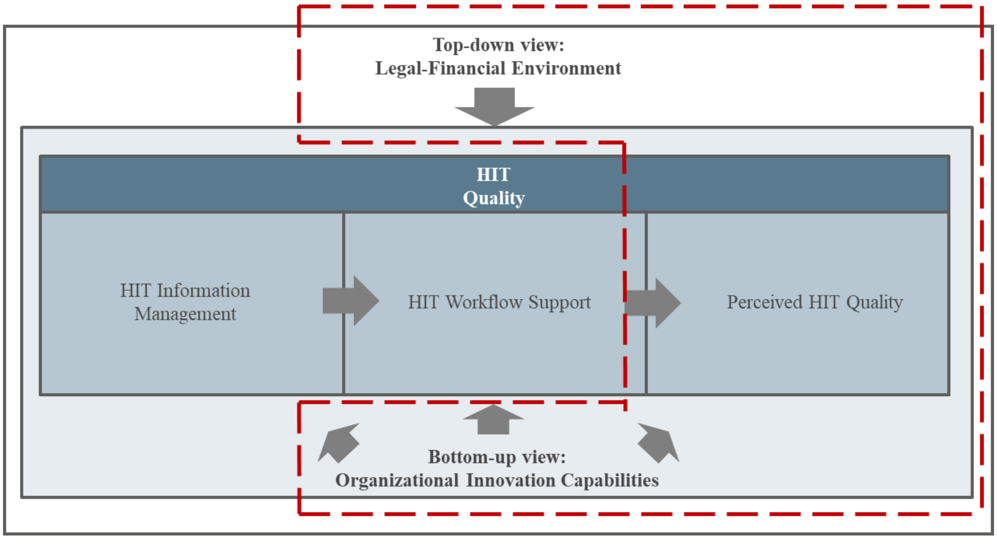
Full paper acceptance rate: 70%

Scimago Journal Ranking: Q3

Topics covered of the conceptual model



Abstract. The establishment of successful clinical information logistics (CIL) within the care processes is one of the main objectives of strategic health IT management in hospitals. While technical realisations in terms of useful, usable and interoperable IT solutions are essential precursors of CIL, there is limited empirical research on what socio-organisational factors underlie an innovation-friendly culture and how they can affect successful information provision. We applied factor analysis on survey data from 403 clinical directors from Germany, Austria and Switzerland and used the dimensions identified to explain the level of CIL with ordered logistic regression analysis. The intensity of collaboration and exchange with the IT department as well as the degree of executive IT leadership showed to be strongly associated with better CIL while personal views and attitudes of clinical directors were not. Analysing country differences revealed the degree of the exchange with the IT department to be significantly lower in German hospitals. This points at a potential strategic lever for German hospital executives to focus on.

Keywords. Organisational culture, diffusion of innovation, clinical information logistics

4.3.1. Introduction

Due to their role as executive managers of the hospital's clinical staff, medical and nursing directors play a crucial role in strategically coordinating care processes – a responsibility that increasingly involves the integration of health information technology (HIT) to generate information at the point of care and to weave it into the care processes [1]. The goal of workflow support through health information technology (HIT) can be tied to the concept of clinical information logistics (CIL), i.e. the principle aiming to provide the right information for the right person, at the right time and in the right quality, making it an important precursor of safe and high quality care [2, 3]. While it is known that adoption rates and IT-quality can substantially differ across organisations [4] and countries [5], we are interested in what generalisable socio-organisational factors are associated with higher levels of CIL. This knowledge will help deduce meaningful levers for strategic IT-management.

Establishing successful CIL is a multifaceted challenge. Building on previous results that point at the importance of an organisation's "innovative power" in the digitalisation of hospital care [6], our goal in this study was to look beyond technical realisations and structural hospital characteristics and focus on underlying aspects of an innovation-friendly culture that can drive better CIL. Herein, we did not only look at peculiarities inherent to the organisation itself but also aimed to better understand the role medical and nursing directors play. This included particularly their personal views and attitudes towards IT as they might be able to establish more successful information logistics within clinical workflows.

This research is part of the international initiative "IT Report Healthcare" that aims at measuring the state of digitalisation in secondary care and related topics across German, Austrian and Swiss hospitals in the context of international developments. Thus, we also aimed at gaining insights about differences in CIL and its socio-organisational covariates in Germany compared to Austria and Switzerland.

4.3.2. Methods

Data analysis was based on a survey that aimed to assess the IT-usage, IT-workflow-support, IT-quality and the socio-organisational environment with regard to innovative HIT from the perspective of nursing and medical directors. Most items were based on existing surveys whereas some scales were newly developed and pretested in two iterations by a total of 14 experts (including executive health professionals, health IT scientists, statisticians, management researchers and one psychologist). The goal was to yield a comprehensive overview on these issues in German, Austrian and Swiss hospitals and therefore targeted medical and nursing directors of 2,421 hospitals. With regard to the socio-organisational environment, we focused on the "innovation capabilities" [7] of the respective respondents and their organisation by issuing a set of statements on related topics and asked for their (dis-)agreement on a 5-point-Likert scale (Table 1).

In order to assess socio-organisational determinants of CIL[19] we used a combined approach by applying an ordered logistic regression analysis on factor scores. Factor analysis was applied in order to investigate and extract underlying dimensions of the scale set. We used polychoric correlation coefficients in the correlation matrix together with unweighted least squares (ULS) estimation since all items were measured on ordinal scales [8]. Applicability of the correlation matrix was evaluated based on the Kaiser-Meyer-Olkin (KMO) criterion and Bartlett's test of sphericity. Factors were extracted if their eigenvalue exceeded 1, if all components explained at least 50% of the total variance and based on assessing the scree plot.

The factor scores obtained from the final factor solution were then used to predict the level of CIL using ordered logistic regression and controlling for hospital size, ownership (profit vs. non-profit), health system affiliation and the existence of a surgery room. These demographics are known to potentially influence IT adoption levels [9, 10] and therefore might also be influencing successful CIL. Data was tested for multicolliniarity and proportional odds of the independent variables. For comparing country differences of the extracted factors and the perceived level of CIL in German vs. non-German hospitals we additionally performed t-tests on the factor scores and a Mann-Whitney-U-test on the level of CIL.

4.3.3. Results

We received completed responses from 403 out of a total of 2,421 hospitals contacted (response rate: 16.6%). 81.4% of responses came from Germany (response rate: 16.8%; nGER = 328), 9.1% from Austria (response rate: 14.2%; nAUT = 37), and 9.5% from Switzerland (response rate: 18.0%; nCH = 38). Data from Austria and Switzerland were pooled and contrasted with those from Germany to obtain more balanced group sizes.

Table 1. Factors and factor loading matrix. Loadings below .25 are left blank (n = 403).

Item	Factor			
	1	2	3	4
Factor "Executive IT leadership"				
"Our executive board actively promotes the initiation of innovative IT projects."	-.89			
"Our hospital shows great agility/flexibility when it comes to implementing new IT solutions."	-.63			
"Our executive board regularly perceives IT as a mere expense factor."	.55			
"Our executive board explicitly demands ideas and suggestions on how to innovate our IT."	-.51			
"I have often received positive feedback for putting forward innovative ideas."	-.37			
Factor "Exchange with IT department"				
"Our IT department gives users a better understanding of the benefits of IT."		.87		
"Our IT is capable to react quickly in face of changing requirements."		.86		

[19] CIL was measured on a single ordinal scale, referring to the entirety of the organisation. Respondents were asked to indicate their (dis-)agreement with the statement "Our hospital always provides the right information, at the right time, at the right place, for the right persons, and in the right quality to support clinical processes.".

“The CIO incorporates suggestions and works with us to develop appropriate solutions.”		.77		
“If there are any questions about IT, I have a personal contact person in the IT department.”		.54		
“The IT department does not really seem to be present in our hospital.”		-.53		
"We openly communicate/discuss new IT projects in our hospital among all involved staff."		.49		
“In our hospital, IT is considered early on in most medical or nursing innovations.”		.42		
Factor “Proactive behaviour”				
“I regularly talk to people from outside our hospital about new IT solutions for our hospital.”			.76	
"I regularly take time to think about IT-based optimisations of our hospital operations."			.75	
"I actively call for new IT solutions to improve clinical processes."			.64	
"I regularly seek to discuss strategic IT issues with our CIO"			.55	
Factor “Health IT attitude”[20]				
“IT solutions are often incompatible with the norms and values of nursing and medical care.”				.61
“Experience has shown that new IT projects tend to make things more difficult than easier.”				.59
“IT undermines medical and nursing autonomy in patient care.”				.56

The data set showed to be suitable for factor analysis with a KMO measure of .92 and according to Bartlett’s test of sphericity with $p < .001$. We attained a final set of 20 items reflecting 4 factors that explain 62% of the total variance (Table 1). Reliability measure ranged from 0.62 to 0.87 indicating solid internal consistency (Table 2). The second factor “exchange with IT department” proved to be significantly higher in Austria and Switzerland compared to Germany whereas all other factor scores did not differ across countries (Table 2). Furthermore, the Mann-Whitney-U-test result indicated a significantly higher ($p=.005$) level of successful CIL in the non-German countries ($\bar{x} = 3.30 \pm 1.10$) compared to German hospitals ($\bar{x} = 2.77 \pm 1.09$).

Table 2. Reliability and factor score differences between German and non-German hospitals (n = 403).

Factor	Cronbach's α	$\bar{x}$ German	$\bar{x}$ non-German	SD (German)	SD (non-German)	p-value
(1) Executive IT leadership	.79	.04	-.12	.96	.84	.25
(2) Exchange IT department	.87	-.06	.34	.94	.83	.00
(3) Proactive behavior	.76	.05	.03	.87	.98	.86
(4) Health IT attitude	.62	.01	-.10	.79	.81	.31

Prediction of the level of CIL through ordered logistic regression demonstrate significant influences of “executive IT leadership” and “exchange IT with department”. “Proactive behaviour” and “health IT attitude” did not affect CIL significantly (Table 3). The model controls for potential demographic covariates (hospital size, ownership (profit vs. non-profit), health system affiliation and the existence of a surgery room), none of which were significantly associated with CIL. Overall, it explains about 44% of the variance in CIL (Cox and Snell pseudo R^2). Assumptions about the absence of multicollinearity and proportional odds are met according to VIF measures way below 4 for all predictors and a non-significant result of the test of parallel lines.

[20] The factor is inverted. Stronger agreement on these three items technically implies a worse attitude towards HIT since the statements are negatively worded. The same kind of inversion applies to the first factor.

Table 3. Ordered logistic regression model ($chi^2 = 202.8$, $df = 8$, $p<.001$) with ** $p<.001$ for coefficient.

Independent Variables	Ordered Logit Coefficient
Executive IT leadership	-.66**
Exchange with IT department	1.30**
Proactive behaviour	.05
Health IT attitude	-.03

4.3.4. Discussion

Four consistent factors could be identified from statements of medical and nursing hospital directors in Austria, Germany and Switzerland: the degree to which the hospital executives promote and lead change towards innovative HIT-solutions, the degree of exchange and collaboration with the IT department, the personal proactive behaviour in IT matters and the personal attitude towards HIT. These factors fit well with comparable structures found in previous works focussing on the CIO's point of view [7]. Support and encouragement from the executive board as well as a collaborative and user-centred approach in IT management have also been pointed at as essential predictors for innovative HIT to prosper [10, 11]. Our study carried on these findings adding the strong association of these two factors with better clinical information logistics (CIL). However, on the personal level of the respondents, behavior and attitudes do not seem to alter CIL.
In accordance with lower adoption rates [5], the perceived level of CIL showed to be lower in German hospitals compared to Austria and Switzerland. When extending the view on factor differences, it is interesting to note that the collaboration with IT departments appears to be closer and more active in the non-German hospitals while the other factors did not differ across countries. This points at a potential deficit in strategic IT management in German hospitals and should be taken up in further research. The studies main limitation stems from modest response rates across countries that might have caused a non-response bias. Results should therefore be subject to further validation in future research.

4.3.5. Conclusion

While shifts in organisational cultural are inherently difficult [12], our study points at the significant influence of an innovation friendly culture in terms of support from the executive board and the exchange of the IT department with the clinicians on successful information logistics in clinical processes. Results should encourage particularly German hospital executives to strategically work towards greater collaboration.

4.3.6. Conflict of Interest

The authors declare no competing interests.

4.3.7. Acknowledgements

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4.4. **Publication 4:** Professionalism of Information Management in Health Care: Development and Validation of the Construct and Its Measurement

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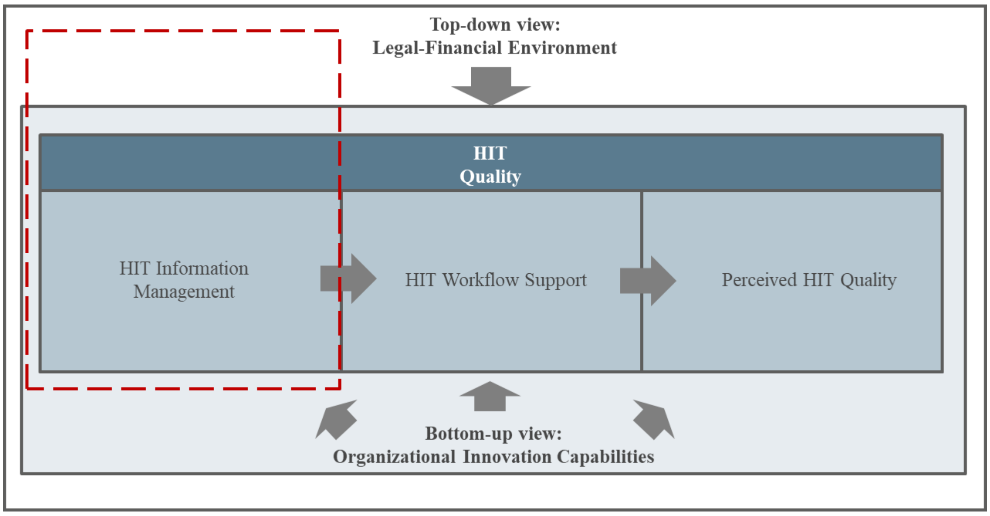
Topics covered of the conceptual model



Abstract.

Background: Against the background of a steadily increasing degree of digitalization in health care, a professional information management (IM) is required to successfully plan, implement, and evaluate information technology (IT). At its core, IM has to ensure a high quality of health data and health information systems to support patient care.

Objectives: The goal of the present study was to define what constitutes professional IM as a construct as well as to propose a reliable and valid measurement instrument.

Methods: To develop and validate the construct of professionalism of information management (PIM) and its measurement, a stepwise approach followed an established procedure from information systems and behavioral research. The procedure included an analysis of the pertaining literature and expert rounds on the construct and the instrument, two consecutive and comprehensive surveys at the national and international level, exploratory and confirmatory factor analyses as well as reliability and validity testing.

Results: Professionalism of information management was developed as a construct consisting of the three dimensions of strategic, tactical, and operational IM as well as of the regularity and cyclical phases of IM procedures as the two elements of professionalism. The PIM instrument operationalized the construct providing items that incorporated IM procedures along the three dimensions and cyclical phases. These procedures had to be evaluated against their degree of regularity in the instrument. The instrument proved to be reliable and valid in two consecutive measurement phases and across three countries.

Conclusion: It can be concluded that professionalism of information management is a meaningful construct that can be operationalized in a scientifically rigorous manner. Both science and practice can benefit from these developments in terms of improved self-assessment, benchmarking capabilities, and eventually, obtaining a better understanding of health IT maturity.

Keywords. Information management, professionalism, health information technology, construct, validation

4.4.1. Introduction

In light of the ongoing progress toward the digitalization of health care delivery, researchers and information technology (IT) professionals have repeatedly stressed the increasing need for effective and efficient information management (IM) to provide safe and high quality care.[1-3] Efforts to digitize workflows are subject to a variety of barriers at the stage of IT initiation, implementation as well as institutionalization.[4] Risks can emerge from the misalignment between the IM strategy and the overall strategy of an organization as well as from the misalignment of workflows, i.e., poor workflows which are digitized without being optimized beforehand.[4,5] Against this background, it becomes clear that a professional IM is of central importance for a successful transition from the paper to the digital world and for its advancement toward better patient care.

The literature on IM reflects the interest in this topic and suggests a variety of approaches. It is argued that a professional IM is required on various levels and its activities must be performed in a regular and repeatable fashion to leverage successful implementations and overcome barriers.[6–8] At this, IM should manage people, structures, processes, and strategies in a goal-oriented manner to ensure the high quality of the health information systems concerned as well as the provision of information and thereby the support of patient care.[1,7,9,10] In addition to long-term planning and execution, IM is also concerned with the daily business.[1,9,11,12]

Information management should be distinguished from IT management. They are two distinct areas but are frequently used synonymously. In addition, depending on the point of view, they can also be used in a hierarchical manner where one of the two fields is considered to be at a higher level.[13–15]

In the present paper, we speak of IM as the area where information, IT, and other pertinent resources must be best aligned with an organization's strategy. In detail, IM is planning, monitoring, and directing of information systems, information, and communication technologies as an overarching management task, with the aforementioned goal of ensuring the best possible use of information resources with regard to the organization's goals.[1,13]

However, the question is what exactly does a professional IM look like? To be able to research, assess, and improve the professionalism of IM, it is necessary to better understand the concept behind it. Comprehending the essence professionalism of information management will lead to a reliable and valid assessment instrument that makes the current state measurable, visible, and comparable on a concise and aggregated level. Preferably, such instrument is a scale that results in scores reflecting the degree of professionalism of information management, i.e., PIM scores. PIM scores could be used for research and as national as well as international benchmarks. In particular, health IT maturity research could benefit from them as performance indicators to be associated with the successes and failures of health IT implementation and use. Finally, such scores can become a suitable self-assessment tool for practitioners as well.

4.4.2. Objectives

Against this background, the main objective of the present study is to examine and determine the construct of professionalism of information management in health care. Therefore, this study aims to specify and operationalize the construct of professionalism of information management. This construct should offer the possibility to provide a system of scores for reflecting the degree of professionalism that breaks down the construct into one key indicator as well as into scores of related professionalism of information management dimensions.

The score system will be developed focusing on hospitals representing health care delivery organizations that are usually large and complex enough to have a strong need for a fully developed IM. The model of MacKenzie et al[16] will hereby serve as a methodological backbone for a construct definition, measurement and validation to reach the objectives of this study. It is a particularly rigorous and well elaborated framework which had proved useful to develop the workflow composite score (WCS) that measures the degree of workflow support through IT in selected clinical workflows and, thus, the technical maturity.[17–19]

The following research questions guided the construct identification, measurement, and validation process.

1. How can the professionalism of information management construct be specified?
2. How can the professionalism of information management construct be measured in a suitable inventory?
3. How reliable and valid is the professionalism of information management measurement?

4.4.3. Methods

Overview

Pursuant to the model of MacKenzie et al,[16] this study followed eight consecutive steps. Table 1 shows the individual steps in detail, whereby the methodological questions and methods per individual step are listed separately in the second and third columns. The fourth column indicates the year of implementation. The first phase of the study could be divided into the steps one to three. The first data collection and construct revision took place in phase two, which embraced steps four to six. Phase three consisted of the steps seven and eight, which were dedicated to conducting the second survey and finally to test for validity and reliability.

Conceptualisation and Definition of the Construct (Step 1)

First, a comprehensive literature research was conducted to define the essence of IM on all levels, distinguishing it from other constructs (mainly IT governance) and identifying the elements of professionalism in conjunction with IM. The search was performed in the relevant databases (i.e., PubMed, ACM, AISeL). The keywords *information management*, *IT governance*, *strategy*, *framework*, *ITIL*, and *COBIT* as well as *validity*, *reliability*, and *evaluation* were used individually and in combination.

The literature search was complemented by a snowball search starting with the work of Winter et al[1] and the IT frameworks COBIT (control objectives for information and related technology) and ITIL (IT infrastructure library).[8,20,21] After the literature research, an internal expert panel of five medical informatics scientists came together to identify the key elements and key terms in the literature and hereupon constituted the professionalism of information management construct and its dimensions.

Table 1. Steps undertaken to develop the construct measurement instrument[16].

Steps	Related questions	Methods	Year
(1) Conceptualisation and definition of the construct	• What is the construct and how does this construct differ from others? • What are the main attributes of the construct?	• Literature search and analysis • Expert group discussions based on the literature findings • Definition of a framework of dimensions based on the literature and discussions	2015
(2) Development of measures – Generate items of the construct	• What dimensions fully represent the conceptual construct?	• Operationalisation of the construct • Definition of scales per item	2015
(3) Development of measures – Assessment of the content validity	• Do the dimensions capture all the relevant attributes of the construct (completeness)?	• Expert group discussion	2015
(4) Scale evaluation and refinement – First quantitative survey	• Are the items understandable (comprehensibility)? • Is the use of the inventory practicable (feasibility)?	• First quantitative survey	2016
(5) Model specification – Specify the measurement model	• How are the dimensions associated with their respective item set as well as with one another?	• Model specification	2016
(6) Scale purification and refinement	• How good is the measurement model/are the scales?	• Explorative factor analysis (EFA) • Expert group discussion	2016

(7) Validation – Data capture and computation – Second quantitative survey	• How good is the revised model and the related parameters?	• Second quantitative survey • Confirmatory factor analysis (CFA) for the assessment of convergent and discriminatory validity	2016/17
(8) Validation – Examination of PIM construct reliability and validity	• How reliable is the PIM? • How valid is the PIM?	• Computation of the reliability (internal consistency) • Computation of the validity	2018/19

Abbreviations: CFA, confirmatory factor analysis; EFA, explorative factor analysis; PIM, professionalism of information management.
Source: Adapted from MacKenzie et al[16].

Development of Measures – Generate Items of the Construct (Step 2)

Once the construct had been defined, a framework for mapping this construct onto the respective items had to be designed. The framework consisted of the potential dimensions of IM and phases of IM. Based on this framework, descriptive and concise item sets including the corresponding categories and Likert scales for each dimension of IM were derived from the literature. For the development of scales and items, established survey instruments were used as the basis.[21,22] This framework served as the method to operationalize the professionalism of information management construct.

Development of Measures – Assessment of the Content Validity (Step 3)

The content validation was performed through an on-site expert workshop. To this end, independent experts were asked to appraise the construct including the item set and scales and to adapt it, if necessary. The panel of experts consisted of six chief information officers (CIOs) and six medical informatics scientists. During this process, individual items were adapted.

Scale Evaluation and Refinement – First Quantitative Survey (Step 4)

After the items had been consented to, a first quantitative survey was conducted using an online questionnaire that was implemented with the online tool *Unipark*. A heterogeneous group of ten CIOs completed the questionnaire and gave detailed feedback in a pretest. Next, the questions were embedded in a comprehensive survey on IM in German hospitals. Following the pretest of the questionnaire, 1,284 CIOs of German hospitals were invited via e-mail. The survey was conducted from February to April 2016 and yielded 164 responses (response rate 12.7%).

Model Specification – Specify the Measurement Model (Step 5)

The dimensions of the professionalism of information management construct were operationalized with five and six items for each dimension, respectively. Once a set of items, which fulfilled the requirements of content validity, had been constructed, the next step was to define a measurement model that captured the expected relationships between the items and the dimensions (step 1). All of the items within the professionalism of information management dimensions should contribute equally to the respective dimension in the sense that no weighting scheme needs to be applied, an item can only belong to one dimension and the dimensions themselves can correlate.

Scale Purification and Refinement (Step 6)

In this step, the model was explored and refined employing statistical methods, in particular explorative factor analysis (EFA). The purpose was to assess if the data were mapped on the previously designed model specifications. This initial, unsupervised approach was chosen against the background that this instrument was newly developed. Then, the EFA was coupled with subsequent confirmatory factor analysis (CFA) (see Step 7-Validation—Data Capture and Computation—Second Quantitative Survey) on a new dataset. According to the literature, the sample sizes were sufficient for both, the EFA and CFA, especially considering the relatively simple factor model and the mid to high communalities and loadings in both solutions.[23–27] The following equation expresses the principle elements of the factor analysis, which is explained below, as these elements will be interpreted in the results.

$$y_{pi} = \lambda_{pq} f_{qi} + \varepsilon_{pi} \quad (1)$$

y_{pi} is the individual value i of the pth observed variable, f_{qi} is the individual value i of the qth latent common factor, ε_{pi} is the individual value i of the pth latent unique factor (error variance), and λ_{pq} is the factor loading indicating the relationship between the pth observed variable and the qth latent common factor.[28,29] Since our data were categorical and ordinal, we applied the underlying variable approach using polychoric correlation coefficients in the correlation matrices and estimated the model coefficients using the unweighted least squares procedure as is widely recommended in the methodological literature in these cases.[30,31]

The model's sampling adequacy was evaluated based on the Kaiser-Meyer-Olkin criterion with an acceptance range of ≥0.7 and following Bartlett's test of sphericity.[32,33] All of the analyses were conducted in *R* using the package *psych*. If the criteria were not met, the variables with low variance caused by all the factors or variables with high factor loadings on more than one factor were removed. The factors included in the EFA can be found in (Table 2).

To improve the wording, all the items were scrutinized by a panel of experts (five CIOs and seven medical informatics scientists). Pursuant to their comments, the items were supplemented, combined to one item or split into two. Finally, the item set consisted of 15 statements on the professionalism of information management dimensions.

Table 2. Component loading matrix for the explorative factor analysis (EFA) (n = 164).

	Item	Factor		
		1	2	3
Strategic IM	Preparation and development of a project portfolio.	0.80		
	Strategic monitoring in the form of targeted evaluations and collection of key figures.	0.72		
	Long-term finance and investment planning.	0.71		
	Preparation and further development of an information management strategy.	0.65		
	Strategic control in the form of prioritisation and initiation of projects.	0.60		
Tactical IM	System analysis and evaluation (e.g. process modelling, evaluation of the current state).		0.84	
	System specification (e.g. requirements definition, specifications, migration plan).		0.78	

	System selection (e.g. market analysis, tendering, bid comparison).	0.71	
	System implementation (e.g. implementation strategy and adaptation).	0.61	
Operational IM	Management and monitoring of the technical performance (e.g. infrastructure, networks).		0.93
	Application support and maintenance.		0.89
	Running of the help desk and/or service desk.		0.83
	Training of clinical end users.		0.71

Abbreviation: IM, information management.
Note: Values below 0.3 are left blank.

Validation – Data Capture and Computation – Second Quantitative Survey (Step 7)

To further extend the validation beyond a mere German perspective, Swiss and Austrian CIOs were also contacted in addition to the German CIOs in the second round of data collection. A group of five CIOs completed the questionnaire and gave detailed feedback in a pretest (four from Germany, one from Austria). The final questionnaire was sent to 1,349 German CIOs, 135 Swiss CIOs and 185 Austrian CIOs via an online questionnaire using the online tool *LimeSurvey* (Appendix 1). The surveys took place from December 2016 to mid-2017 as part of the IT Report Health Care.[34]

A total of 223 responses out of the original dataset (224 German, 14 Swiss and 13 Austrian participants) were complete (i.e., had no missing values) and could thus be used for the analysis and calculation of a CFA. A factor model was specified according to the results of the initial analysis (see step 6) and the CFA was conducted to assess the scale convergent and discriminatory validity based on this second dataset in *R* using the *lavaan* package. In accordance with the previous EFA procedure, parameter estimates were calculated based on polychoric correlation coefficients and a diagonally weighted least squares procedure with robust corrections to standard errors and test statistics. The model was also specified to allow for interfactor correlations. Model fit was evaluated drawing on the root mean square error of approximation, comparative fit index, Tucker-Lewis index and standardized root mean square residual.

Validation – Examination of PIM Reliability and Validity (Step 8)

In addition to the CFA, Cronbach's α was calculated as a means to further test the scale in terms of its internal consistency. An α value greater than 0.7 was considered acceptable.[10,35]

To calculate a professionalism of information management score from the survey results, the different items were transformed to a scale ranging from 0 to 100 to allow for aggregation. A mean value was calculated across the respective dimensions and across all dimensions. In addition, a mean value was calculated for the individual items to show the degrees of implementation. For testing the criterion validity of the measurement instrument, correlations between the professionalism of information management scores and two related criteria, which had been added as extra questions, were performed. These two criteria for the validation were (1) usage of an IT framework and (2) availability and integration of a strategic IT plan. In detail, the items were:

- Do defined IT management processes exist in your institution in terms of IT governance (e.g., based on COBIT or ITIL)?
- Does your institution have a strategic IT plan and to what extent is it integrated into the strategic hospital plan?

The criterion of IT frameworks can be regarded as an upstream criterion that could promote the professionalism of information management[5,8,36] while the integrated IM strategy corresponds to a downstream criterion that is developed as part of a professionalism of information management.

4.4.4. Results

Specification of the Construct: Professionalism of Information Management

The first question: "How can the professionalism of information management construct be specified?" was answered in steps 1 to 3. The professionalism of information management construct could not be explicitly found in the international IM literature. It rather stood in a network of more or less similar theoretical constructs (Table 3). There were strong references to the construct about the main terms (IT) governance, IM procedures, IT frameworks as well as phases (performing cycle) of IM. It was also possible to find influencing environmental determinants of professionalism of information management (Table 3). Following the literature search and subsequent expert discussions (steps 1 to 3), professionalism of information management was regarded as the regularity with which the sum of all IM activities (procedures) were performed and which ensured that IT properly contributed to the fulfilment of the hospital goal of patient care.[9]

Table 3. Constituent and environmental terms of the professionalism of information management construct.

Constituting terms	Environmental terms
(IT) governance[1,8,20,36-38]	Structures[1,7,21,39,40]
Procedures of IM[1,9,21]	Socio-technical aspects[41,42]
Levels of IM[1,7,9]	
IT frameworks[8,20,21,43,44]	
Phases of IM (performing cycle)[1,21,43]	

Abbreviations: IM, information management; IT, information technology; PIM, professionalism of information management.

According to the literature (Table 3), *governance* embraced all activities to ensure the general conditions were established that determined the achievement of the corporate goals. It served as a framework for decision-making and executing tasks at various levels,[1,36] with the intention to support IM activities leading to better IT performance and thus information as well as information system quality.[8,21,37,38,44] In other words, IT governance was a condition which IT needed to prosper and to bemanagedwell.[8,38] In contrast, IM planned, directed, and monitored these activities that were specified within the framework of governance.[8,21]

Information management itself, which was performed within the scope of IT governance, was composed of actions or *IM procedures* which were performed on different levels. Therefore, IM embraced practices and activities to achieve the goals of the organization.[21]

Based on Winter et al.,[1] there were three different *levels of IM* on which the procedures could be executed following the need to cover the range from short-term to long-term actions, i.e., operational tasks to long-term planning and evaluation. This would also result in different levels of consequences because different views on IM requiring different methods and tools would be taken.[1] Based on this assumption, a distinction could be made between the levels of strategic, tactical, and operational IM. The strategic IM dealt with the long-term perspective on the entire information processing in an organization. The tactical IM was responsible for the functions and applications and was initiated as the next step following strategic IM. Thus, a strategic IM was compellingly necessary for a tactical one. The operational IM, finally, was in charge of operating the components of the information system and processes.[1,7,9] Exemplary processes at the strategic level were long-term finance and investment planning as well as preparation and further development of an IM strategy.

Pursuant to the literature analysis and the discussions in the expert panel, the levels of a strategic, tactical, and operational IM were regarded as good candidates for the *dimensions of IM*.

The IT frameworks COBIT for IT governance and ITIL for IT service management were found to provide information about the *degree of professionalism of information management*. Offering tools to support IM in adopting and implementing IT and IT innovations,[20,43,44] they addressed, amongst others, methods to enforce *routinization*. Hereby, routinization was understood as the way in which IM procedures were performed, i.e., *periodic*, *unplanned (ad hoc)* or *not at all*.[8,21] This meant, the more regularly a given process was performed, the more repeatable and thus more stable, safe, effective, and efficient it became.[8]

The literature analysis also showed that standardization and regularity were augmented by the notion of a *cyclic way of performing* these procedures, i.e., starting from *planning*, then *implementing*, and finally *evaluating* before *planning* again. This meant that any IM action was split into activities before, during, or after an intervention. Thus, the activities of any kind were part of a repetitive and systematic cycle[1,21,43] that also expressed the fact of whether an IM action was performed professionally.

Consequently, the professionalism of information management should be defined by the *elements* of (1) regularity of IM procedures and (2) the distinction of procedures belonging to different cyclic phases. This held true for IM procedures on each of the three levels of strategic, tactical, and operational IM.

These activities had to be distinguished from the structures and sociotechnical aspects that possibly exerted an influence on IM. Structures were necessary prerequisites or environmental aspects from which procedures were derived. Typical examples of structures were “the existence of an IT department” or “the positioning of a CIO and his responsibilities within the hierarchy of the organization."[1,7] Moreover, the implementation of procedures influenced people (or were influenced by people), which constituted the sociotechnical environment.[41,42] These structures and sociotechnical aspects, although they are associated, were found to be distinct from the professionalism of information management construct. Figure 1 shows how the professionalism of information management construct emerged from the literature analysis and the expert panel discussions.

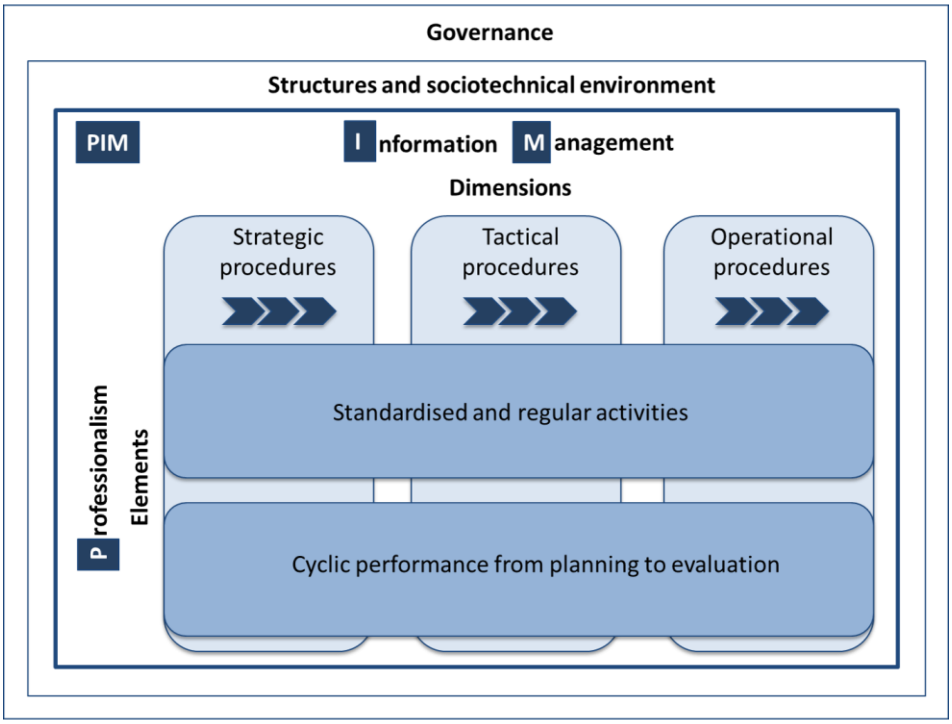


Figure 1. Conceptualization and definition of the construct of the professionalism of information management (PIM) to a literature research.

Following the definition of the construct, a set of items was developed, whereby the items reflected activities on the strategic (five items), tactical (six items) or operational (six items) level, i.e. the IM dimensions, and could be assessed according to the elements of professionalism in terms of standardization and regularity, i.e. whether the activity took place regularly, irregularly or not at all. Furthermore, IM activities were included that reflected professionalism from the perspective of planning, implementing, and evaluating the cycle (Table 4).

Table 4. Items resonating the professionalism of information management (PIM)[1]

	Items	Primary phase
Strategic IM	Preparation and development of a project portfolio.	Planning
	Strategic monitoring via targeted evaluations and collection of key figures.	Evaluation
	Long-term finance and investment planning.	Planning
	Preparation and further development of an information management strategy.	Planning
	Strategic control in the form of the prioritisation and initiation of projects.	Planning
Tactical IM	System analysis and evaluation (e.g. process modelling, evaluation of the current state).	Evaluation
	System specification (e.g. requirements definition, specifications, migration plan).	Implementation
	System selection (e.g. market analysis, tendering, bid comparison).	Implementation

	System implementation (e.g. implementation strategy and adaptation).	Implementation
	System evaluation (information gathering, preparation and presentation)	Evaluation
	Project management (project planning, support and completion)	Planning
Operational IM	Management and monitoring of the technical performance (e.g. infrastructure, networks).[a]	Implementation
	Application support and maintenance.[a]	Implementation
	Running of the help desk and/or service desk.[a]	Implementation
	Training of clinical end users.	Implementation
	IT related accounting.	Implementation
	Contract management.[a]	Implementation

Abbreviations: IM, information management; IT, information technology.
[a]There are overlaps with IT service management.

Measuring the Professionalism of Information Management Construct

Following steps 1 to 3 for the construct definition and development of measures, steps 4 to 6 were conducted, to further answer the second question: "How can the professionalism of information management construct be measured in a suitable inventory?" To this end, a first round of utilizing the items for data capturing and analyzing them by an exploratory factor analysis (EFA) was performed. The results of the EFA (Table 2) confirmed the dimensions of professionalism of information management as separate factors, i.e., IM on the strategic, tactical, and operational level. It also led to a slight adjustment of the item set due to high factor loadings on more than one factor or due to variables with low variance extracted caused by all factors. The measure of sampling adequacy for the EFA across all criteria was 0.86 and the total variance explained by all factors was 66.54%.

Reliability and Validity of the Professionalism of Information Management Measurements

The third question "How reliable and valid is the professionalism of information management measurement?" was answered in steps 7 to 8. The second comprehensive survey based on a revised questionnaire and on an independent international dataset of answers from 223 CIOs confirmed the construct of professionalism of information management. Figure 2 shows the results of the CFA and confirmed the tripartite division of IM according to the strategic, tactical, and operational dimensions.

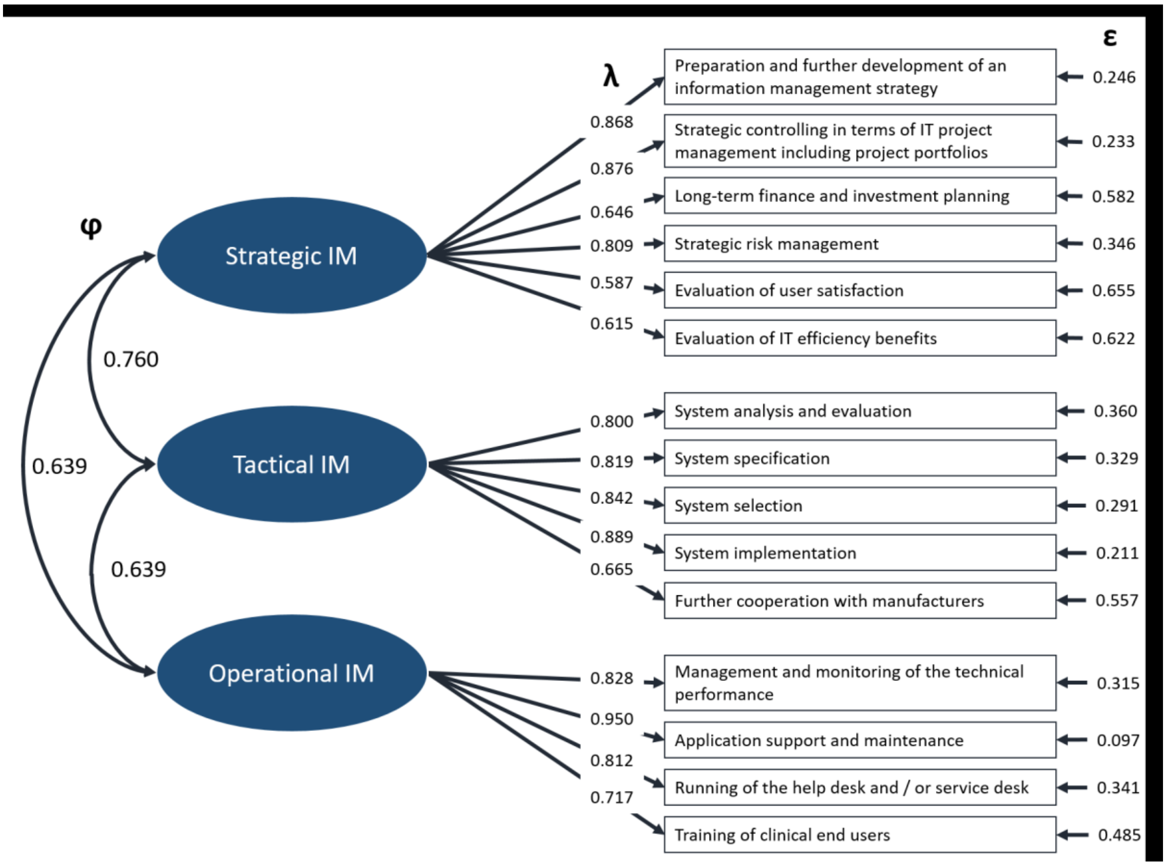


Figure 2. Confirmatory factor analysis (CFA) path diagram including factor correlations, factor loadings, and error variances (n = 223).

The item "evaluation of user satisfaction" (introduced after the expert panel at step 6) was initially defined as an operational item, but it was loaded on the strategic IM and finally assigned to it. Despite the moderate to high correlations between the latent variables, psychometric properties proved to be good overall and indicated the satisfactory fit of our model to the data (Table 5).

Table 5. Goodness-of-fit statistics of the confirmatory factor analysis (CFA) (robust DWLS estimation).

df	χ^2	CFI	TLI	RMSEA	SRMR
87	173.202	0.967	0.960	0.067	0.075

Abbreviations: CFI, comparative fit index; df, degrees of freedom; DWLS, diagonally weighted least squares; RMSEA, root mean square error of approximation; SRMR, standardized root mean square residual; TLI, Tucker-Lewis index; χ2, chi square.

The professionalism of information management score system developed from the item set is shown in Table 6 together with the corresponding reliability measure Cronbach's α. The professionalism of information management overall score reflects the mean of how professionally IM procedures were performed across all three IM dimensions. The scores are shown for the model version 1 (step 4) and version 2 (step 7). The professionalism of information management overall score of version 2 could be broken down into three countries, i.e., Germany, Austria, and Switzerland, as shown in Table 6. Furthermore, the professionalism of information management overall score was split into three IM dimensions, called dimension subscores, and the IM phases, called phase subscores.

Table 6. Cronbach's α, PIM score system, and descriptive statistics.

		Items		α		Mean[b]		SD[b]	
Model version[a]		**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**
PIM overall		13	15	0.88	0.88	43.2	64.8	18.7	19.2
Germany[c]		-	-	-	-	-	64.2	-	19.3
Austria		-	-	-	-	-	71.5	-	15.6
Switzerland		-	-	-	-	-	67.9	-	20.2
Dimension	Strategic IM	5	6	0.82	0.81	30.2	54.2	26.1	24.6
	Tactical IM	4	5	0.81	0.81	44.9	60.7	17.4	23.4
	Operational IM	4	4	0.91	0.74	57.8	85.7	24.7	20.1
Phase	Planning	4	4	0.79	0.81	33.2	64.8	27.1	28.4
	Implementation	7	8	0.85	0.81	52.1	74.2	18.5	18.9
	Evaluation	2	3	0.28	0.56	32.0	39.5	21.2	22.9

Abbreviations: α, Cronbach's Alpha; IM, information management; PIM, professionalism of information management; SD, standard deviation.
[a]Model version 1 (*n* = 164)—first survey; Model version 2 PIM overall and operational IM (*n* = 223), strategic IM and tactical IM (*n* = 224), implementation (*n* = 223), planning and evaluation (*n* = 224) —second survey.
[b]Value range 0 to 100.
[c]Germany (*n* = 199), Austria (*n* = 11), Switzerland (*n* = 13).

Overall, the scales indicated good psychometric properties across both survey iterations and stayed stable after minor adjustments had been made to the scale sets, i.e., number and wording of the items. The α value of the "operational IM" scale decreased from survey one to two but remained at an acceptable level of above 0.70. The α value of "evaluation" was very low at 0.28 in the first round. By splitting an item, the reliability could be increased to 0.56. There was a rise of the mean values in all professionalism of information management dimensions as well as in the overall score from survey one which took place in 2016 to survey two which took place primarily in 2017. Operational IM obtained the highest score values, while strategic IM was the lowest. This finding was consistent across the two surveys. The scores for the phases planning, implementation, and evaluation were the least high for evaluation, followed by planning. The highest score was achieved for implementation (individual medians for each professionalism of information management item see Appendix 2).

Validity was tested by correlating the overall professionalism of information management score as well as the subscores with two related criteria. The results of the correlation with the criterion "Do defined IT management processes exist in your institution in terms of IT governance (e.g. based on COBIT or ITIL)?" as well as with "Does your institution have a strategic IT plan and to what extent is it integrated into the strategic hospital plan?" are shown in Table 7.

Table 7. Correlation results to the measurement of validity.

	A strategic IT plan exists and is integrated into a strategic hospital plan[a]	***n***	**Defined IT management processes in terms of IT governance (COBIT, ITIL) exist[b]**	***n***
PIM overall	.57*	223	.36*	223
Strategic IM	.56*	224	.33*	224

Tactical IM	.47*	224	.30*	224
Operational IM	.39*	223	.24*	223
Planning	.57*	224	.32*	224
Implementation	.50*	223	.31*	223
Evaluation	.42*	224	.30*	224

Abbreviations: COBIT, control objectives for information and related technology; IM, information management; IT, information technology; ITIL, IT infrastructure library; PIM, professionalism of information management.
[a]Correlation according to Spearman-Rho.
[b]Correlation according to point-biserial.
[c]The correlation is significant at the 0.01 level.

All correlations between these criteria and the professionalism of information management scores yielded significant results at a significance level of 0.01.
The criterion “strategic plan” correlated to a considerably high degree with the overall professionalism of information management score and was decreasingly associated along the three levels strategic, tactical, and operational IM, thus reflecting the distinction between the three levels of the dimension very well. The correlations with the criterion “use of IT frameworks” resembled the ones with the criterion “strategic plan,” but at a lower level of the correlation coefficients.

4.4.5. Discussion

Summary

This study shows the results of the development and validation process for a construct to express the degree of professionalism of information management in health care and its measurement instrument. The construct of professionalism of information management designed from an initial literature study is composed of the dimensions strategic, tactical, and operational IM and the elements of professionalism, i.e., the standardization and regularity of procedures as well as the distinction between the planning, implementation, and evaluation phase. All IM procedures in the three dimensions and the three phases are described regarding how standardized they are and how regularly they take place.

Validity of the Constructs

The professionalism of information management construct reflects the degree with which an organization forces and realizes the implementation of an integrated strategic IT plan. This is demonstrated by the significant and considerably high positive correlation of the professionalism of information management overall score with the strategy criterion. This finding is supported by the literature which highlights the importance of strategic IM for tactical and operational IM.[1,7] Similarly, the implementation of IT frameworks is related to the professionalism of information management construct as is indicated by the significant and positive correlation with professionalism of information management overall and the decreasing positive correlations from strategic to operational IM. However, this finding is less pronounced as in the case of the implementation of the strategic plan, which is mirrored here by all the scores. This result is backed by the literature that confirms that these instruments lead to formalized procedures and process empowerment.[8,21]

Strength of the Constructs – Development of a Construct Stable Over Time

Two consecutive comprehensive surveys and the resulting factor analyses (EFA and CFA) confirmed the structure of professionalism of information management regarding its dimensions. Reliability and validity showed good results for the construct in terms of its IM dimensions and phases. Thus, a model for the professionalism of information management construct that is stable over time could be developed. It embraces a conclusive explanatory model for the operationalization of professionalism of information management from which a measurement instrument was compiled. The professionalism of information management construct thus constitutes the basis of a reliable and valid instrument for assessing the degree of professionalism of information management that can be utilized in many practical ways, e.g., for benchmarking health care institutions—also across countries as well as for individual assessments of a single institution. The development of the professionalism of information management construct stands out in relation to other maturity models in health care, such as EMRAM (Electronic Medical Records Adoption Model),[47] due to its IM focus and in particular due to the transparency of what is measured and how it is measured (reliability and validity). Compared with other measurements of IM maturity such as COBIT or ITIL, professionalism of information management can be easily used for population-wide assessments. From a scientific point of view, it may also serve for gaining better insight into information system success and other phenomena that strongly depend on a professional IM.

Adjustments of the Measurement Instrument

The professionalism of information management measurement instrument differed between the two surveys as some items had to be changed (as described in “Scale Purification and Refinement (Step 6)”) in accordance with the experts’ votes, such as the addition of an item on strategic risk management. Therefore, the instruments are not entirely identical. There were considerable and consistent differences in the PIM score magnitude between the first and second survey with higher values in the latter measurement. The aforementioned adjustment of the items could have led to this finding. These results can also reflect an actual increase from the first to the second measurement point. This cannot be totally ruled out as IM has gained more attention recently.[48]

Empirical Survey Results: PIM Score

The focus of this work was put on the development of the professionalism of information management construct and its related measurement tool resulting in a score system. However, the empirical findings of the two successive surveys in addition reveal facts about the status of IM and its professionalism. In particular, it can be seen that the professionalism of operational IM is the one that is most pronounced compared with tactical and strategic IM. This indicates severe deficits in these areas. Maybe these activities are not given high enough priority by the top management team of the organization. It could also be due to a lack of staff in the IT department and a high workload so that only the most urgent operational tasks can be performed. Similarly, it could be a matter of competencies. Not all IT managers are trained to take on responsibilities at the strategic level. The missing strategic orientation is associated with the findings that the planning and implementation scores were higher than the evaluation score. It indicates that projects are planned and implemented, but that sustainable monitoring and steering according to the evaluation results rarely take place.

Limitations

When interpreting the results, various limitations must be taken into account. This study is limited with regard to the response rates of the two surveys of 12.7 and 13.4% (included answers) that might have caused a nonresponse bias.

Furthermore, focusing on Austria, Germany, and Switzerland, the empirical evidence stems from German speaking countries. However, the professionalism of information management construct as well as the corresponding measurement tool draw extensively on the international literature and thus incorporate a perspective that ensures generalizability.

It could be argued that the three IM dimensions, i.e., strategic, tactical, and operational IM, are not distinct because there is a high intercorrelation between the three levels. However, we do not assume that these dimensions are independent either, which is why a low or nearly zero correlation would be surprising. Given that the CFA is not rotated oblique, a "medium-strong" correlation is acceptable.[49]

In terms of reliability, the operational IM showed a slight decrease between the first and second survey, possibly due to the adaptation of the questions. The α value of "evaluation" in the first round amounting to 0.28 was very low. By adding an item on user satisfaction, the value could be increased to 0.56. Further items should be added in future rounds, if applicable. Generally spoken, the reliability values, however, remained acceptable.

Future Work

In addition to specifying the professionalism of information management construct consisting of strategic, tactical, and operational IM as well as of the distinction between the planning, implementation, and evaluation phase, the literature discusses a further effect on professionalism of information management. The relevant literature suggests an influence on professionalism of information management exerted by the IT relevant structures and sociotechnical aspects, i.e., the resources and position of the CIO, professionalism of information management.[7,50] Future approaches could, therefore, examine which effects structures have on the PIM scores, e.g., whether there are structures that can increase the professionalism of information management. It also becomes possible to investigate the extent to which professionalism of information management has an impact on IT outcomes, e.g., on IT innovations as well as IT quality and how it relates to the sociocultural aspects of innovation and change.

It is also worth considering not only to concentrate on CIOs but also to include the voice of the chief executive officers (CEOs) on this topic to obtain a more comprehensive picture. This point of view promises new insights because it is particularly the CEO who decides about IT in hospitals and health systems today.[51]

To implement the PIM score as a permanent measure of the professionalisms of IM, it should continue to be surveyed within the framework of benchmarking rounds. This allows a long-term view on the evolution of IM to be obtained. By means of a benchmark, it can provide scientific information and it directly reflects the results to practitioners.

4.4.6. Conclusion

Using an iterative process, we could define a construct as well as develop a reliable and valid instrument to measure it. The degree of professionalism of information management is defined by the dimensions of strategic, tactical, and operational IM as well as by the elements of professionalism, i.e., the standardization and regularity of the IM procedures and their allocation to the planning, implementing, and evaluating cycle. Thus, professionalism of information management as a construct and assessment tool can be used for various practical and research purposes, e.g., for national and international comparisons of IM capabilities or as predicting constructs of health IT maturity and information systems success. As a result, professionalism of information management can serve as a catalyst for best practice or the science-practice dialogue, in which it identifies the potential for IM improvements at the individual, organizational level as well as at the level of the health care system.

4.4.7. Annotations

Parts of this work were published at the International Conference on Wirtschaftsinformatik (WI 2017) in St. Gallen[52] (first study on the professionalism of IM and its dimensions. Hypothesis-based research model taking into account IT governance and IT entrepreneurship) and the Medical Informatics Europe (MIE 2018) in Gothenburg[53] (excerpt and slightly modified analysis of professionalism of information management in a reliable and valid way in German hospitals as well as the impact of hospital characteristics). However, none of the publications embrace the full stepwise development of the professionalism of information management construct and its measurement.

4.4.8. Acknowledgements

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4.5. **Publication 5:** The Effect of Innovation Capabilities of Health Care Organizations on the Quality of Health Information Technology: Model Development with Cross-sectional Data

Published as: **Esdar, M.**, Hübner, U., Thye, J., Babitsch, B. & Liebe, J. D. (2021). The Effect of Innovation Capabilities of Health Care Organizations on the Quality of Health Information Technology: Model Development with Cross-sectional Data. *JMIR Medical Informatics*, 9(3): e23306.

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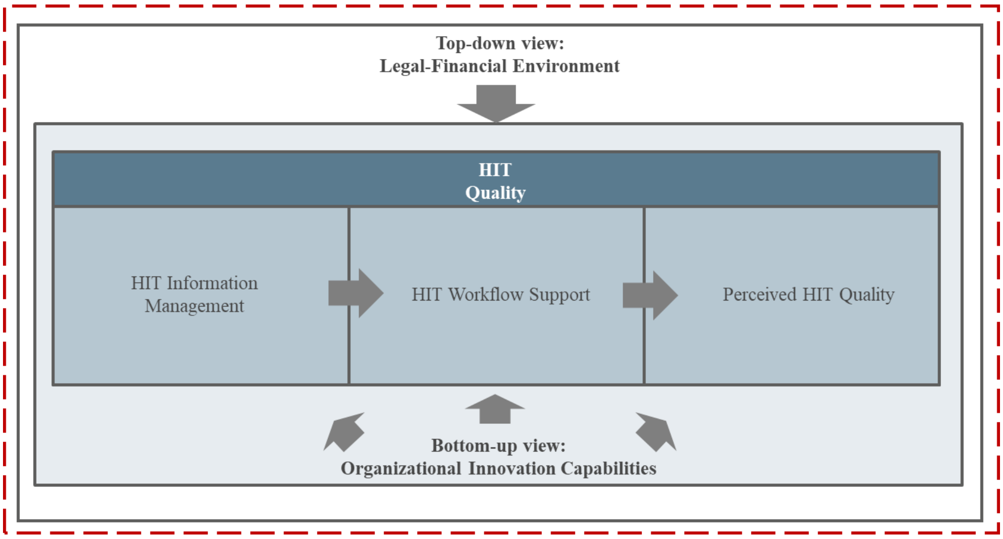
Topics covered of the conceptual model



Abstract.

Background: Large health organizations often struggle to build complex health information technology (HIT) solutions and are faced with ever-growing pressure to continuously innovate their information systems. Limited research has been conducted that explores the relationship between organizations' innovative capabilities and HIT quality in the sense of achieving high-quality support for patient care processes.

Objective: The aim of this study is to explain how core constructs of organizational innovation capabilities are linked to HIT quality based on a conceptual sociotechnical model on innovation and quality of HIT, called the IQ_{HIT} model, to help determine how better information provision in health organizations can be achieved.

Methods: We designed a survey to assess various domains of HIT quality, innovation capabilities of health organizations, and context variables and administered it to hospital chief information officers across Austria, Germany, and Switzerland. Data from 232 hospitals were used to empirically fit the model using partial least squares structural equation modeling to reveal associations and mediating and moderating effects.

Results: The resulting empirical IQ_{HIT} model reveals several associations between the analyzed constructs, which can be summarized in 2 main insights. First, it illustrates the linkage between the constructs measuring HIT quality by showing that the *professionalism of information management* explains the degree of *HIT workflow support* (R^2=0.56), which in turn explains the *perceived HIT quality* (R^2=0.53). Second, the model shows that HIT quality was positively influenced by innovation capabilities related to the top management team, the information technology department, and the organization at large. The assessment of the model's statistical quality criteria indicated valid model specifications, including sufficient convergent and discriminant validity for measuring the latent constructs that underlie the measures of HIT quality and innovation capabilities.

Conclusions: The proposed sociotechnical IQ_{HIT} model points to the key role of professional information management for HIT workflow support in patient care and perceived HIT quality from the viewpoint of hospital chief information officers. Furthermore, it highlights that organizational innovation capabilities, particularly with respect to the top management team, facilitate HIT quality and suggests that health organizations establish this link by applying professional information management practices. The model may serve to stimulate further scientific work in the field of HIT adoption and diffusion and to provide practical guidance to managers, policy makers, and educators on how to achieve better patient care using HIT.

Keywords. organizational innovation, health information management, organizational culture, diffusion of innovation, hospital information systems, organizational change management

4.5.1. Introduction

Background

Discussions on health information technologies (HITs) in research and practice have increasingly shifted from dealing with the question of *if* digital solutions are worth investing in [1,2] to questions on *how* higher degrees of successful digitalization can be achieved [3-6] and how HIT improves processes and outcomes [7-9]. Although the term HIT has been used and defined in various ways, we understand it to encompass the organization's electronic information technologies that health care professionals use to support the care process [7]. These include, but are not limited to, electronic medical records, health information exchange systems, computerized provider order entry, clinical decision support systems, and the related hardware (excluding medical devices) and their integration with each other.

It has been repeatedly demonstrated that large health organizations often struggle to adopt high-quality and modern HIT solutions and are challenged with increasingly shorter innovation cycles of these technologies [10-15]. The fact that there is considerable variation in the adoption and quality of HIT between organizations within and across countries points to the importance of focusing on the organizations themselves in terms of their *inner* capabilities with regard to managerial skills, the promotion of HIT use, project execution, and innovation promotion [16-18]. Although a wide range of general facilitating factors of successful HIT adoption have been acknowledged in several theoretical frameworks [19-24] and various systematic literature reviews [3,12,25-28], little is known about the exact constituents of capabilities of health care organizations to innovate in particular and how they affect not only the adoption of HIT but also their quality. Insights about this relationship could prove valuable for guiding managers, policy makers, and educators toward promoting and developing organizational behavior that facilitates better HIT use, which in turn might lead to improved clinical outcomes [29].

HIT Quality and Innovation Capabilities

HIT adoption is most often understood as the implementation, that is, the introduction of an application, and its acceptance and use in an organization and many adoption studies focus on specific functionalities or applications [12,21,27]. However, the complexity of organization-wide HIT solutions is usually far greater and requires the incorporation of many different facets of the organization's information system [30-33]. In addition, when extending the scope from adoption to the quality of HIT, even more aspects need to be incorporated as quality requirements are typically considered to incorporate not only various technical layers (eg, data and information, functions, hardware, interoperability) to support clinical care processes but also features of information management and the perceived quality of the IT systems [17,23,34,35]. Thus, in our study, we focus on HIT quality rather than mere adoption and consider it to be composed of the following 3 principal domains: HIT information management, HIT workflow support, and perceived HIT quality:

- HIT information management encompasses the full spectrum of strategic, tactical, and operational management tasks to build and operate an organization's information system [34,36]. Management practices are deemed to be essential preconditions for realizing the potential of HIT [37], especially those executed by the information technology (IT) department [38,39] and those that involve systematic clinical user participation [40,41].
- *HIT workflow support* refers to the degree to which an organization has implemented the information technologies needed to support patient care processes. This encompasses the availability of electronic patient data across various care processes as discussed by Liebe et al [42], the availability of clinical applications (eg, electronic medical records, computerized provider order entry, and clinical decision support systems), their integration with one another, and accommodation of hardware solutions. This confluence of technical factors has been discussed as indicative of structural and process quality [17,43].

- Finally, HIT quality manifests itself not only in the technical quality of HIT but also in the subjective assessment of the implemented IT solutions that is hereinafter referred to as the *perceived HIT quality*.

In addition to HIT quality, there is also little understanding about the identification and effect of the organization's capabilities to innovate; however, as van Gemert-Pijnen et al [44] emphasize, many HIT innovations might fail as a result of disregarding the interdependencies between technology and its organizational and cultural environment. In our understanding, innovation capabilities (ICs) refer to the culture regarding HIT at various organizational levels that reflect its ability to innovate, that is, the ability to adopt new HIT solutions (or to renew the existing ones) that enhance the quality of information provision in clinical care processes. These capabilities refer to latent phenomena, that is, they are inherently difficult to capture, as they are expressions of a commonly shared attitude in social networks that leads to certain sets of corresponding behaviors [45,46]. In light of the semantic variations and inconsistent definitions of related phenomena, scholars have pointed to the need for further work to examine this construct and its measurement [47-49]. The lack of measurements also implies that there are few studies that provide empirically tested claims regarding the effect of an organization's ICs on HIT adoption or quality [49,50].

Conceptual Model and Study Objectives

Only a few theoretical frameworks incorporate the peculiarities and complexity of organization-wide HIT solutions in a way that allows for an assessment of its quality and success [23,24,34]. Others acknowledge the facilitating role of domains comparable with ICs [19,20]; however, there is no framework that puts the spotlight on the interrelationship between these 2 constructs and how they might enable better information provision in the care processes. Correspondingly, there is a need for validated measurement scales within such a framework to put its implicit hypotheses into the empirical test. Although some studies have begun to derive related scale sets [51-53], they are not yet ready to measure the full picture of the relationship between the 2 domains. In addition, the few that attempted to test more complex relationships between related constructs have limitations, particularly regarding small sample sizes and rather narrow outcome measures of HIT quality [54-56].

To investigate the sociotechnical interrelationships between ICs and HIT, we propose an initial conceptual model, that is, the IQ_{HIT} (innovation and quality of HIT) model (Figure 1). It rests on the underlying assumption of a directional process of antecedents and consequences of HIT as was similarly conceptualized in studies by Leidner et al [54] and Greenhalgh et al [57]. This is reflected in the assumption that HIT information management affects the degree of HIT workflow support that then determines the perceived HIT quality. Furthermore, these domains can be assumed to be influenced by an organization's ICs. In addition, internal structural characteristics such as the organization's size, teaching status, and ownership as well as external influences in terms of national health policies and legal regulations need to be accounted for as possible covariates in the model, as both have been shown to be significantly associated with HIT use [58-61].

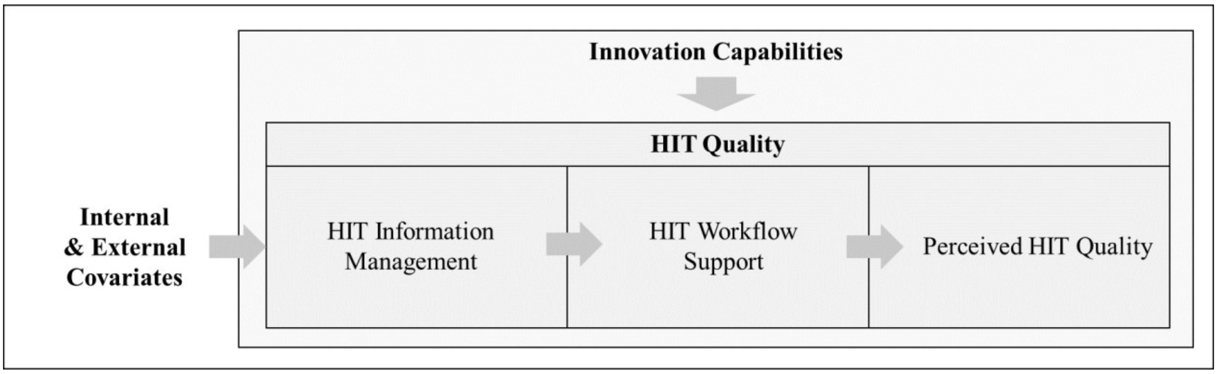


Figure 1: Initial socio-technical conceptual IQ_{HIT} model of the layered relationship between innovation capabilities, HIT quality, and covariates.

On the basis of this model, the research goal was to empirically test and explain how health organizations' ICs are linked to HIT quality.

4.5.2. Methods

Data Collection

Serving as empirical input for the model, data from chief information officers (CIOs) as hospital representatives were obtained. Hospitals are particularly interesting because of both the complexity of their IT and their organizational environment. We chose CIOs as our target group because they have the best oversight of the entirety of the IT landscape and top management issues [62,63]. We included Austrian, German, and Swiss hospitals in our target population to control for external influences in terms of different national health policies. The questionnaire and its constructs were based on the redevelopment and refinement of previous surveys and included a total of 188 question items (Multimedia Appendices 1 and 2) [64]. The final questionnaire was pretested by 5 hospital CIOs, 10 researchers (comprising health IT experts, statisticians, and 1 psychologist), and 1 clinician to evaluate whether the question items were understandable and answerable and whether they were sufficiently precise to measure the organization's information system. This led to some minor adjustments of item scales (response options), changes in the wording of items, and a few supplementary definitions.

Email addresses of 1669 CIOs were compiled through internet and telephone searches. The CIOs were responsible for 2324 hospitals (92% of all 2542 hospitals across Austria, Germany, and Switzerland). Data collection took place during the first half of 2017 via a web-based survey. Of the 1669 emails sent, 1499 had come through and 251 CIOs participated (17% response rate)—19 answers were discarded because of incompleteness (ie, the respondent did not finish the survey or whole sections were left out). The descriptive results were made available in 2018 [65], and as an incentive for participation, CIOs were offered access to a web-based benchmarking dashboard that allowed them to compare their hospital with peer groups [66].

Modeling and Data Analysis

We applied structural equation modeling (SEM) to test various interrelationships between constructs. Specifically, we chose partial least squares structural equation modeling as it is tolerant of the use of categorical data and allows for including reflective measurement models (ie, manifest indicators reflect the latent construct), formative measurement models (ie, manifest indicators form the latent construct), and single-item scales without identification problems [67].

Specification of the Measurement Models

We operationalized each of the 5 domains in the conceptual model (Figure 1), with a total of 10 constructs (Table 1). All items and scales associated with these constructs are detailed in Multimedia Appendices 1 and 2.

Table 1: Overview of the constructs (body) used to operationalize the domains of the conceptual socio-technical IQ_{HIT} model (header).

HIT Quality			Innovation Capabilities	Covariates
HIT Information Management	HIT Workflow Support	Perceived HIT Quality		
Professionalism of Information Management (PIM)	Workflow Composite Score (WCS) including technical descriptors and care processes	Perceived HIT Workflow Support (PHITS)	Innovation Capability: Top Management Team Support (IC TMT)	Structural Characteristics (SC)
Clinical IT-Agents (CITA)		Overall Goodness of Information Provision (OGIP)	Innovation Capability of the IT Department (IC ITD)	Country (COU)
			Organization-Wide Innovation Capability (IC OW)	

HIT Quality

HIT information management was operationalized using 2 constructs. First, we applied a construct that captures the degree of professionalism of information management (PIM) in health care in terms of the regularity of 15 management key tasks and practices, as proposed by Thye et al [36]. As PIM consists of 3 latent and correlated subcomponents (strategic, tactical, and operational information management), we incorporated it as a reflective higher order model with PIM as the higher order construct and the 3 subcomponents as the lower order constructs using the repeated indicator approach [68]. Second, to reflect institutionalized user participation, we included the formal appointment of clinical IT agents as a reflective measurement model with 2 underlying items (one referring to physicians and the other one to nurses).

HIT workflow support can be theorized as being constituted by the descriptors *data and information*, *IT functions*, *integration*, and *distribution* of data and IT functions [17]. These 4 descriptors are the central building blocks of the Workflow Composite Score (WCS), an aggregated score that proved to be reliable and valid in measuring the degree of HIT supported patient care in core clinical processes [17,43,65]: *ward rounds* to reflect diagnostic and therapeutic decision making at the bedside, *presurgery* and *postsurgery* processes that reflect the information flow between departments, and *admission* and *discharge* as core interface processes between outpatient and inpatient care. The WCS comprises 146 items grouped along these 5 clinical processes and the 4 descriptors (Multimedia Appendix 2). We included it in the SEM analysis as a single-item scale, as its composite structure was largely predefined in previous studies [17,65].

Perceived HIT quality was measured using the 2 constructs. First, we asked the CIOs to grade the HIT workflow support (perceived HIT workflow support) in all 5 aforementioned clinical care processes separately and included the resulting indicators in a reflective measurement model. Second, we asked for a concluding assessment (single-item scale) of the overall goodness of information provision, that is, the organization's general ability to provide the right information, at the right time, at the right place, for the right persons, and in the right quality to support patient care processes. This indicator was applied in a previous study [38].

Innovation Capabilities

We investigated this domain and the underlying constructs across the 2 preceding surveys [38,52]. The initial exploratory study on this topic pointed to a latent construct, represented by 5 items that describe the top management team (TMT) support and the organization-wide innovation culture with regard to HIT [52]. A second study signified that the ICs relating to the IT department could be considered as another separate component [38]. To explore the emerging constructs in greater depth, we added 9 items to capture additional details on the TMT support and the organization-wide innovation culture and 6 additional items that refer to the IT department. An exploratory factor analysis using the unweighted least squares estimation and oblique factor rotation was computed, which resulted in a 3-factor structure that reflected ICs at the TMT level (IC TMT), ICs at the IT department level (IC ITD), and ICs at the organization-wide level (IC OW). For SEM, the underlying items were then included in 3 reflective measurement models. A total of 4 items with low outer loadings (<0.50) were removed to establish sufficient convergent and discriminant validity.

Covariates

A total of 2 covariates were included in the model. First, to control for well-known structural characteristics, we included a formative measurement model that was composed of the hospital size (bed count) and its teaching status. Second, the country was included as a single-item scale to account for external conditions. Austrian and Swiss hospitals were pooled to obtain more balanced group sizes.

Specification of the Structural Model

The specifications of the structural model resulted from a step-wise build-up of testing the direct and mediated effects along the components of the conceptual model. Each step was thereby rooted in findings from studies that suggest individual linkages between the constructs, which we summarized into a set of 12 theoretical assumptions (Table 2). On the basis of these assumptions, we deduced one or more hypotheses for specifying the structural equation model paths.

Table 2: Theoretical assumptions and corresponding hypotheses guiding the structural model specification.

Assumption	Exemplary References
1. The professionalism of information management (PIM) might be linked to HIT workflow support. H_1: PIM has a positive effect on the WCS.	Ammenwerth et al. 2006 [69], Avgar et al. 2012 [70], Bradley et al. 2012 [71], Winter et al. 2011 [72]
2. Formal participation in terms of the appointment of clinical IT agents might results from professional information management practices and might lead to better HIT workflow support. H_2: The effect of PIM on the WCS is partly mediated by CITA.	Cresswell and Sheikh 2013 [12], Liebe et al. 2018 [42], Potts et al. 2011 [73], Sligo et al. 2017 [26]
3. There likely is a direct link between the technical and the perceived quality of HIT workflow support. H_3: The WCS has a positive effect on PHITS. H_4: The WCS has a positive effect on OGIP.	Hadji and Degoulet 2016 [74], Hübner 2015 [75], Yusof et al. 2008 [23]
4. The perceived quality of HIT is likely linked to the perceived goodness of information provision. H_5: PHITS has a positive effect on OGIP.	Gorla et al. 2010 [76], Suki 2012 [77]
5. A top management team (TMT) that is capable and willing to innovate might facilitate an innovation-friendly culture throughout the organization, including the IT department. H_6: IC TMT has a positive effect on IC OW. H_7: IC TMT has a positive effect on IC ITD.	Abdekhoda et al. 2015 [78], Carpenter et al. 2004 [79], Laukka et al. [80]
7. The tasks and procedures that manifest PIM might also be facilitated by an innovation-friendly TMT. H_8: IC TMT has a positive effect on PIM.	Bradley et al. 2012 [71], Liebe et al. 2018 [81], Weintraub and McKee 2019 [82]
8. Innovation capabilities of the TMT and the IT department might determine the degree of HIT workflow support. H_9: IC TMT has a positive effect on the WCS H_{10}: IC ITD has a positive effect on the WCS	Esdar et al. 2018 [38], Paré et al. 2020 [56], Leidner et al. 2010 [54]
9. The ability of the IT department to innovate might be linked to information management practices. H_{11}: IC ITD has a positive effect on PIM.	Liebe et al. 2017 [83], Watts and Henderson [84]
10. HIT quality might be a function of the organization-wide climate towards IT. Such climate might also facilitate a stronger effect of the technical HIT quality (i.e. the WCS) on the perceived quality of information provision. H_{12}: IC OW has a positive effect on the WCS. H_{13}: IC OW has a positive effect on PHITS. H_{14}: IC OW has a positive effect on OGIP. H_{15}: IC OW positively moderates the relationship between the WCS and OGIP.	Caccia-Bava et al. 2006 [45], Gagnon et al. 2012 [85], Taylor et al. 2015 [86], Vest et al. 2019 [50]
11. Structural characteristics might be linked to HIT quality, possibly also to the TMT's capabilities to innovate. H_{16}: SC has a positive effect on the WCS. H_{17}: SC has a positive effect on PIM. H_{18}: SC has a positive effect on IC TMT.	DesRoches et al. 2012 [58] Fadol et al. 2015 [87], Kruse et al. 2014 [88], Troilo et al. 2014 [89],
12. Compared to Germany, hospitals from Austria and Switzerland exhibit higher degrees of HIT workflow support and a more pronounced culture toward innovation.	Esdar et al. 2018 [38], Haux et al. 2018 [90], Hübner et al. 2010 [91], Hüsers et al. 2017 [49], Naumann et al. 2019 [11]

H_{19}: COU has a positive effect on the WCS.
H_{20}: COU has a positive effect on IC OW.
H_{21}: COU has a positive effect on IC ITD.

Parameter Estimations and Model Assessment

We applied partial least squares structural equation modeling using SmartPLS version 3 [92]. The measurement models were assessed for internal consistency using Cronbach α and composite reliability. Convergent and discriminant validity was evaluated according to the height of the outer loadings, the average variance extracted, the Fornell-Larcker criterion, and the Heterotrait-Monotrait ratio.

Inner variance inflation factor values were used to test for collinearity within the structural model. Path coefficients and mediation effects were evaluated based on the direct, total, and indirect effects as well as on f^2 effect sizes with *P* values and 95% CIs obtained from 10,000 bootstrap replications. Besides the R^2 values for the endogenous latent variables, we used blindfolding to obtain Stone-Geisser Q^2 values to determine the cross-validated predictive relevance of the exogenous constructs.

4.5.3. Results

Descriptive Statistics

The sample consisted of data from 232 hospitals, most of which were from Germany (Table 3), which corresponds to the higher baseline number of German hospitals. The participating hospitals were rather large, with an average size of 492 (SD 239) beds, and many (112/232, 48.3%) were in public ownership. Nevertheless, hospitals from all relevant demographic categories were included in the sample. The WCS, as the central measure of HIT workflow support in our model, showed an overall mean value of 56 (SD 14) points (ranging between 0 and 100 points; Multimedia Appendix 3). The mean values and SD of the remaining constructs are shown in Multimedia Appendix 1.

Table 3: Demographic characteristics of participating hospitals (n=232).

Characteristic	Value
Country, n (response rate in %)	
Austria	14 (8.8)
Germany	205 (18.3)
Switzerland	13 (11.3)
Ownership, n (% in sample)	
For-profit	42 (18.1)
Non-profit	78 (33.6)
Public	112 (48.3)
Teaching status, n (% in sample)	
Major teaching hospital	22 (9.5)
Minor teaching hospital	101 (43.5)
Nonteaching hospital	109 (47.0)
Member of a hospital group, n (% in sample)	
Yes	140 (60.3)

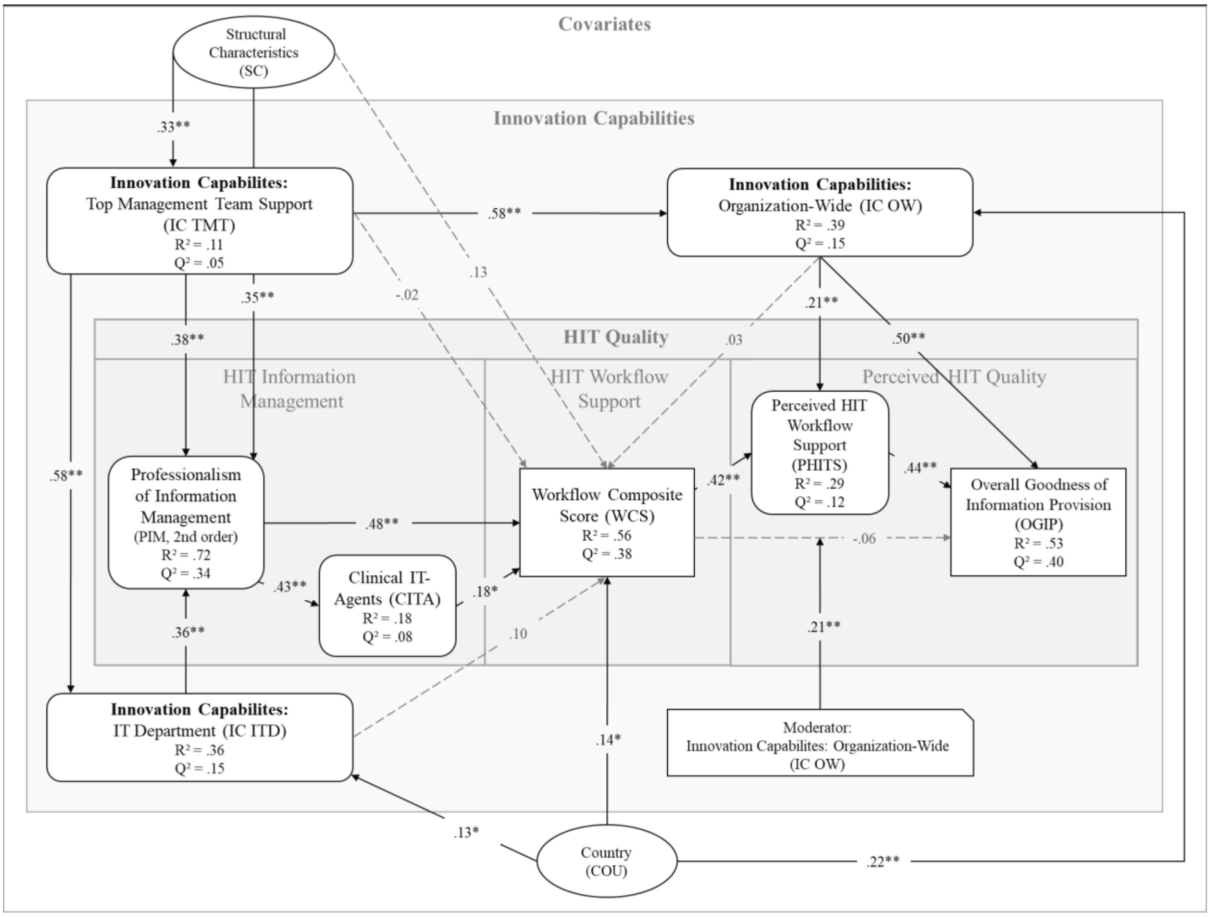
No	92 (39.7)
Number of beds, mean (SD)	491.9 (238.5)

Structural Equation Model

The parameters assessing the measurement models pointed to valid specifications of the reflective models as well as the formative model in terms of convergent validity and internal consistency (Multimedia Appendices 4 and 5). In addition, sufficient discriminant validity was established according to the Fornell-Larcker criterion assessment, as indicated by the Heterotrait-Monotrait ratios of the correlations that were all below the recommended threshold value of 0.85 [93] (Multimedia Appendix 6). No collinearity was found in the structural model, as all the inner variance inflation factor values ranged within the limits of 0.20 and 4. Moreover, the Stone-Geisser Q^2 values of the endogenous variables indicate a good out-of-sample predictive power of the path model, especially with regard to the WCS (Q^2=0.38) and the overall goodness of information provision (Q^2=0.40).

The 21 hypotheses (Table 2) led to a variety of interrelationships in the structural model in terms of direct, mediated, and moderated effects. Approximately 50% of the variance in the key constructs for measuring HIT quality, the HIT workflow support (as measured by the WCS), and the perceived overall goodness of information provision (OGIP) could be explained by the model (Figure 2).

Within the HIT quality domain, the results showed a strong effect of PIM on the WCS with a path coefficient estimate of 0.48 (P<.001). This association was partially mediated by the use of clinical IT agents to a small but significant extent (Multimedia Appendix 7). Furthermore, WCS was associated with OGIP via an indirect effect between the 2, which was mediated by the perceived HIT workflow support. The exact P values of the path coefficients are shown in Multimedia Appendix 8.



*p < .05; **p < .01

Figure 2: The structural model of IQ_{HIT} with path coefficients, explained variance (R^2) and predictive relevance measures (Q^2) of the endogenous constructs. Latent constructs are displayed with rounded edges, the exogenous covariates as ellipses and the moderator variable with a cut-off corner.

Within the innovation layer, the IC TMT exhibited a strong effect on IC ITD and IC OW.

Furthermore, the model revealed a strong association between innovation and quality at various levels (the total and indirect effects are given in Multimedia Appendix 7): the ICs of the TMT and of the IT department significantly and similarly affected PIM, whereas IC OW had a strong effect on the perceived HIT quality in terms of OGIP and a weaker but still significant effect related to perceived HIT workflow support. Contrary to some of our initial assumptions, as expressed in hypotheses H9, H10, and H12, there was no significant direct effect of any of the constructs representing IC on the WCS (Table 4). Instead, the results showed significant indirect effects of IC TMT and IC ITD on the WCS mediated by PIM (Multimedia Appendix 7). The effect of the WCS on OGIP, which did not become significant, was, however, significantly moderated by IC OW (hypothesis H15). In summary, ICs possessed many points of application at the HIT quality path, that is, at the beginning influencing PIM and later affecting the overall quality of information provision for patient care.

Table 4. Summarized results of the hypothesis tests in reference to P values < .05.

Hypothesis	Support by the model
H_1: PIM has a positive effect on the WCS.	supported
H_2: The effect of PIM on the WCS is partly mediated by CITA.	supported
H_3: The WCS has a positive effect on PHITS.	supported
H_4: The WCS has a positive effect on OGIP.	not supported
H_5: PHITS has a positive effect on OGIP.	supported
H_6: IC TMT has a positive effect on IC OW.	supported
H_7: IC TMT has a positive effect on IC ITD.	supported
H_8: IC TMT has a positive effect on PIM.	supported
H_9: IC TMT has a positive effect on the WCS	not supported
H_{10}: IC ITD has a positive effect on the WCS	not supported
H_{11}: IC ITD has a positive effect on PIM.	supported
H_{12}: IC OW has a positive effect on the WCS.	not supported
H_{13}: IC OW has a positive effect on PHITS.	supported
H_{14}: IC OW has a positive effect on OGIP.	supported
H_{15}: IC OW positively moderates the relationship between the WCS and OGIP.	supported
H_{16}: SC has a positive effect on the WCS.	not supported
H_{17}: SC has a positive effect on PIM.	supported
H_{18}: SC has a positive effect on IC TMT.	supported
H_{19}: COU has a positive effect on the WCS.	supported
H_{20}: COU has a positive effect on IC OW.	supported
H_{21}: COU has a positive effect on IC ITD.	supported

With regard to the covariates, the country had a significant effect on the WCS and was also associated with higher degrees of IC ITD and IC TMT, albeit with rather small effect sizes f^2 (Multimedia Appendix 8). The organization's structural characteristics did not exhibit a direct effect on the WCS in our model but instead on the *preceding* latent variables in the model, namely, PIM and IC TMT.

4.5.4. Discussion

Principal Findings

On the basis of data from 232 hospitals in Austria, Germany, and Switzerland, a sociotechnical IQ_{HIT} model was developed and tested. To the best of our knowledge, this is the first model that investigates HIT quality in light of the organizations' ability to innovate. It does so in a strictly empirical manner using a validated instrument. The model sets out the internal composition of HIT quality in establishing a consecutive connection between HIT information management, HIT workflow support, and perceived quality. Furthermore, an organization's ICs were positively associated with HIT quality at various levels. Most notably, an innovation-friendly attitude on the TMT level appeared to strongly but indirectly facilitate HIT-based workflow support, mediated by professional information management practices.

The Inner Workings of HIT Quality

At the core of the IQ_{HIT} model, the WCS was used to measure HIT quality in terms of the workflow to support the IT solutions provided for improving patient care. The WCS is a multifaceted indicator that consists of a plethora of underlying items (Multimedia Appendix 2). By incorporating it, the model considers the complexity of interdepartmental and multifunctional health information systems.

According to the model, HIT workflow support depends on professional information management, that is, professionally conceptualized and performed activities at the strategic, tactical, and operational levels, as has been conjectured by Winter et al [34] and empirically conceptualized by Thye et al [36]. Only the HIT workflow support that is managed in an orderly and professional manner by the IT department can work properly regarding data and information provision, IT functions in place, their integration with one another, and the ability to distribute the data and the information to the point of care. Part of this effect is mediated by the presence of clinical IT agents, confirming the importance of establishing a formal link between IT department information management and clinical end users. Interestingly, the structural characteristics (bed count and teaching status) did not affect the HIT workflow support directly but only via the mediating effect of professional information management. This is rather surprising, as most studies suggest a direct link, particularly between the size of an organization and its HIT use [25].

HIT quality was conceptualized to encompass both, a technical component that bundles manifest, self-reported attributes about the information system, that is, the WCS, and a subjective judgment about its perceived quality. According to the CIOs' viewpoint, the very abstract judgment of the perceived goodness of information provision appears to not be directly linked to the WCS but requires some intermediate interpretation, that is, the perceived HIT workflow support, which refers to a more detailed perspective of admission, ward rounds, presurgery and postsurgery, and discharge processes. This also suggests that there is no strict automatism between a high degree of HIT quality in terms of its technical components and the perceived quality of information provision in an organization. This points to the need for good implementation practices of HIT interventions to successfully reap their benefits.

Innovation Capabilities in Health Care Organizations

The IQ_{HIT} model also specifies the inner fabric of organizational IC. The underlying scales yielded good psychometric properties and reflected an innovation-friendly attitude and behavior at different organizational levels: at the executive level (IC TMT), the items mirror the motivational and monetary support of the TMT for IT innovation and their proactive engagement with respective projects as part of the organization's vision. Similar to the views in the Upper Echelons Theory, which stresses the crucial role of senior leadership in fostering innovation, this factor had a strong predictive relevance across the model [94]. IC ITD reflect the kind of CIO leadership that facilitates creativity, communication, and participation of end users. On the third level (IC OW), openness and widespread flexibility for embracing new IT solutions that prevail throughout the organization at large were the defining elements. Most of these characteristics were suspected [47,95,96] and partly known [27,97,98] to facilitate innovation in a variety of contexts; however, the way they statistically cluster along different organizational levels and their different effects has not been specified before. Therefore, the innovative capacity of health organizations cannot be viewed as monolithic blocks or mere buzzwords. Its contents are woven throughout various organizational levels to varying degrees. This study did not explicitly focus on how these capabilities can be built or how they are determined. However, when controlling for the covariates, we found that TMT support is a function of certain structural characteristics, namely, a higher bed count and teaching status, both of which can be interpreted as indicators of greater financial flexibility in terms of slack resources. However, ICs at the IT department and the organization at large depend on the respective country. More precisely, these 2 domains are more pronounced in Austria and Switzerland than in Germany, which corresponds well with previous findings on different samples [11,49].

HIT Implementation Between Innovation and Quality

Traditionally, empirical research conducted on HIT quality has frequently disregarded aspects of innovation, and both have often been discussed separately from one another [75]. Our model establishes a connection between the two by showing that attaining high levels of HIT quality is facilitated and mediated by an organization's ability to create space for creativity, agility, and communication in relation to IT-based innovation.

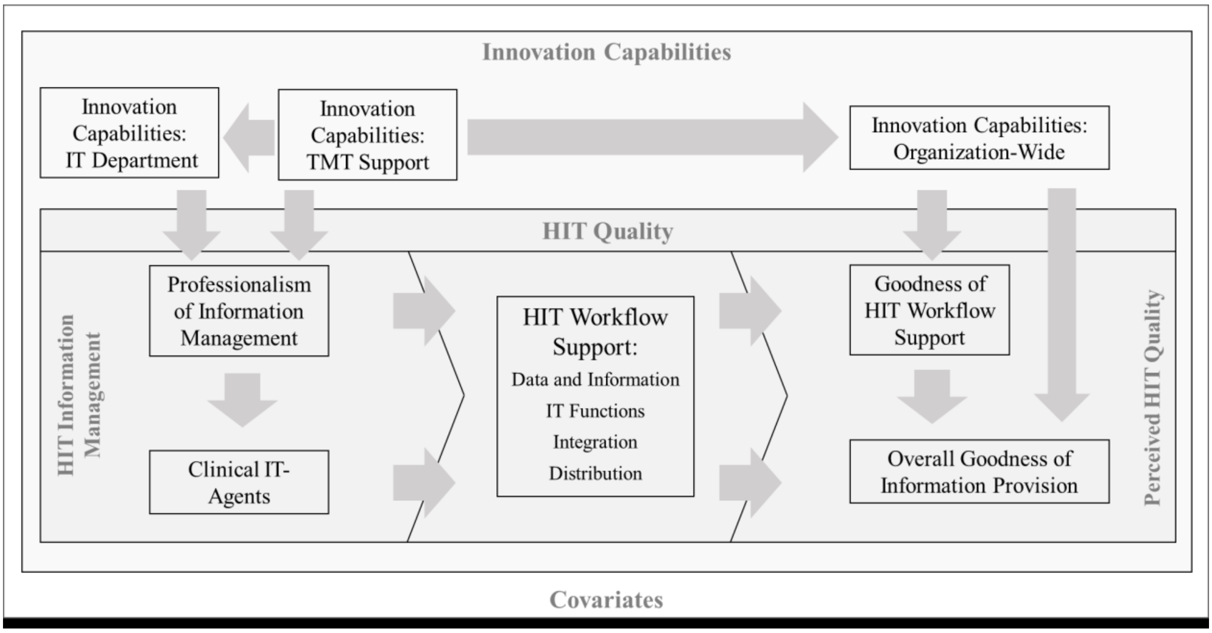


Figure 3. The IQ_{HIT} model.

Overall, the structural model (Figure 2) can be translated into a more schematic model (Figure 3) based on the major findings. It shows that PIM mediates the effects of the 2 IC domains—IC TMT and IC ITD—on HIT workflow support, which illustrates the interplay between the *right attitude* toward innovation and formalized management practices for innovational strength. The attitude and intent to innovate play an important role in and of itself; however, professional information management is needed for the practical execution of this intention to improve HIT workflow support.

Furthermore, we found IC OW to partly moderate the relationship between the HIT workflow support and the perceived OGIP, implying that there might actually be a direct effect between the 2 as long as the organization is agile, flexible, and open toward IT (equals high levels of IC OW). This could be interpreted as an indication that an organization-wide positive attitude toward using the IT in place, irrespective of how advanced it actually is, leads to better information provision in the clinical care processes, at least from the vantage point of CIOs. Overall, it becomes clear that ICs are not only needed at the TMT level but also at the IT department level and throughout the organization to establish high-quality HIT solutions. Executive managers and policy makers should therefore consider how to establish higher levels of these capabilities at various levels.

Limitations

Our study had several limitations. Most notably, this is an observational study, and despite the statistical specifications that might suggest otherwise, it cannot be inferred that the relationship between constructs is truly causal. For instance, there might be temporal displacements between the current beliefs of executives and higher degrees of HIT quality as implementation processes take time [99].

Furthermore, this sociotechnical model reflects the perspective of the CIOs and their points of view of the HIT cosmos and ICs. This is both a strength and a weakness. The strength is its consistency and authenticity regarding technical and organizational issues related to IT. Its weakness is the CIOs cannot accurately evaluate clinicians' view on the timely and correct provision of data and information (ie, the *right side* of the model), which requires a more detailed assessment in future research. Ultimately, the clinical outcome is the improvement or stabilization of the patient's condition. None of this is captured in this model, as it mirrors the vantage point of CIOs. The next step will be to develop a model that incorporates the views of physicians and nurses. This approach can also cope with potential common-method biases. The sample is also based on voluntary participation, which is why we cannot rule out a nonresponse bias in the data.

Finally, not all possibly relevant factors at play can be accurately accounted for in one model, which is reflected by the R^2 values that leave parts of the variance in the endogenous constructs unexplained. Given these limitations, further studies are needed to validate and differentiate the relationships between and within IC and HIT quality, and our model provides various access points to do so.

4.5.5. Conclusions

On the basis of survey data provided by the CIOs of 232 hospitals, we proposed a sociotechnical IQ_{HIT} model to explain how organizational innovation relates to various facets of HIT quality. Although some associations in the model could be presumed by the literature, it clearly and uniquely highlights the key role of ICs and information management for HIT-based workflow support. Thus, it demonstrates that innovation and quality do not contradict each other. In particular, an innovation-friendly attitude of TMT and the IT department determines the degree of HIT workflow support, albeit not directly, but by means of professional information management practices that eventually facilitate the perceived goodness of information provision for patient care. This suggests that managers of health organizations should strive for both a more pronounced culture toward innovation and professional information management to translate such a culture into HIT quality. Furthermore, the IQ_{HIT} model might be useful for studies on HIT adoption and diffusion and for the definition of HIT maturity models. To this end, it provides validated measurement scales that can be utilized in future research.

4.5.6. Acknowledgements

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4.5.7. Conflicts of Interest

None declared.

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5. Discussion

5.1. Results Synthesis Across the Publications

The digital transformation in healthcare organizations involves a myriad of different barriers and facilitators at the macro-, meso-, and micro-level. This thesis aimed to shed light on organizational mechanisms at the meso-level, specifically how health organizations might facilitate the quality of their HIT systems by means of their innovation capabilities while considering different legal-financial environments on the macro-level. To do so, a stepwise, quantitative approach to iteratively develop relevant measures (in accordance with Research Question 1) across four surveys and to study their interrelationships (Research Question 2) which culminated in the proposal of the IQ_{HIT} model. Table 6 illustrates the results of this stepwise approach by summarizing each publication's key findings and corresponding implications for the next steps within the thesis, which were then picked up by the subsequent publications 2-5.

Table 6: Key findings and contributions of the publications. RQ = Research Question.

Publication	Key finding or contribution to the thesis	Implications for subsequent steps
Publication 1 Innovative Power of Health Care Organisations Affects IT Adoption: A bi-National Health IT Benchmark Comparing Austria and Germany	**1a**: The perceived innovative power of healthcare organizations has a significant influence on HIT adoption (RQ2) **1b**: HIT adoption and the perceived innovative power differ between German and Austrian healthcare organizations (RQ2)	To further differentiate the constituent elements of “innovative power” and for analyzing its relationship to HIT in greater detail. *Picked up in Publication 2, 3 and 5*
Publication 2 Exploring Innovation Capabilities of Hospital CIOs: An Empirical Assessment	**2a**: Innovation capabilities can be differentiated based on whether they refer to personal and organizational components (RQ1) **2b**: The organizational component reflects the strategic support provided by the top management teams as well as a fundamentally positive attitude toward HIT within the organization as a whole (RQ1)	Further investigations of innovation capabilities and their relationship with HIT quality are needed. *Picked up in Publication 3 and 5*
Publication 3 Determinants of Clinical Information Logistics: Tracing Scio-Organisational Factors and Country Differences from the Perspective of Clinical Directors	**3a**: Innovation capabilities at the organizational level can be further differentiated: With regard to the top management team and with regard to the IT department (RQ1) **3b**: Those two components appear to be influencing the perceived HIT quality (RQ2) **3c**: Innovation capabilities appear to differ between Germany on the one hand and Austria and Switzerland on the other hand (RQ2)	To further examine the influence & function of the IT department and to additionally consider "manifest" features of HIT workflow support. *Picked up in Publication 4 and 5*

Publication 4 Professionalism of Information Management in Health Care: Development and Validation of the Construct and Its Measurement	**4a**: The professionalism of information management can be broken down into 3 dimensions: strategic, tactical, and operational information management activities (RQ1) **4b**: Development and validation of an instrument to measure these dimensions (RQ1)	To use measurement scales for investigating antecedents & consequences of professional information management with regard to innovation capabilities and HIT quality. *Picked up in Publication 5*
Publication 5 The Effect of Innovation Capabilities of Health Care Organizations on the Quality of Health Information Technology: Model Development with Cross-sectional Data	**5a:** Organizational innovation capabilities were further differentiated into 3 distinct components: With regard to the top management team, the IT department, and the entire organization (RQ1) **5b:** Development of a revised version of the workflow composite score for measuring HIT workflow support **5c:** Development of measures for the perceived HIT quality **5d:** Organizational innovation capabilities, especially with respect to the top management team, significantly influenced HIT quality (esp. the HIT workflow support and perceived HIT quality) (RQ2) **5e:** Professional information management is a central mediator between the innovation capability of the top management team and of the IT department on the one hand and HIT workflow support on the other (RQ2) **5f:** The country influences the HIT workflow support and the innovation capability of the top management team and IT department (RQ2)	-

The numbered key findings of each publication in Table 6 are also used in Figure 7 to depict how each finding integrates into the overall thesis.

Publication 1 essentially applied a first version of the conceptual model by only focusing on some of its core elements. The results pointed to a significant link between the innovative power of healthcare organizations and the adoption of a set of HIT functions which are part of the workflow composite score (finding 1a). This led to the conclusion that both domains required further differentiation throughout the next steps.

Regarding the development of the organizational innovation capabilities, Publication 2 first introduced multi-item scales, and the results suggested a distinction between personal and organizational capabilities (finding 2a). The former, however, was not the focus of this thesis and was thus not taken up in the following works. In Publication 3, the organizational component was further differentiated based on whether the innovation capabilities refer to the top management team or the IT department – this time as evaluated from the perspective of clinical directors (finding 3a). Finally, exploratory factor analysis in Publication 5 led to a factor solution with three distinct components: one referring to the TMT support, one to the IT department, and one to the organization at large (finding 5a).

With regard to HIT quality, Publication 3 introduced a measure of the perceived HIT quality which showed to be influenced by organizational innovation capabilities relating to the TMT and IT department (finding 3b). Furthermore, the construct developments in Publication 4 led to the proposal of a scale for measuring information management professionalism as part of the HIT quality domain that distinguishes strategic, tactical, and operational practices (finding 4a & b). By additionally including a revised version of the WCS as a measure of HIT workflow support, the full spectrum of the HIT quality domain as proposed in the conceptual model was then used in Publication 5.

The specification of the legal-financial environment's influence in the final model was based on the results of Publication 1 and 3. Herein both the innovation capabilities and the measures of HIT quality showed to be slightly higher in the non-German countries, i.e., Austria and Switzerland (findings 1b and 3c) compared to Germany.

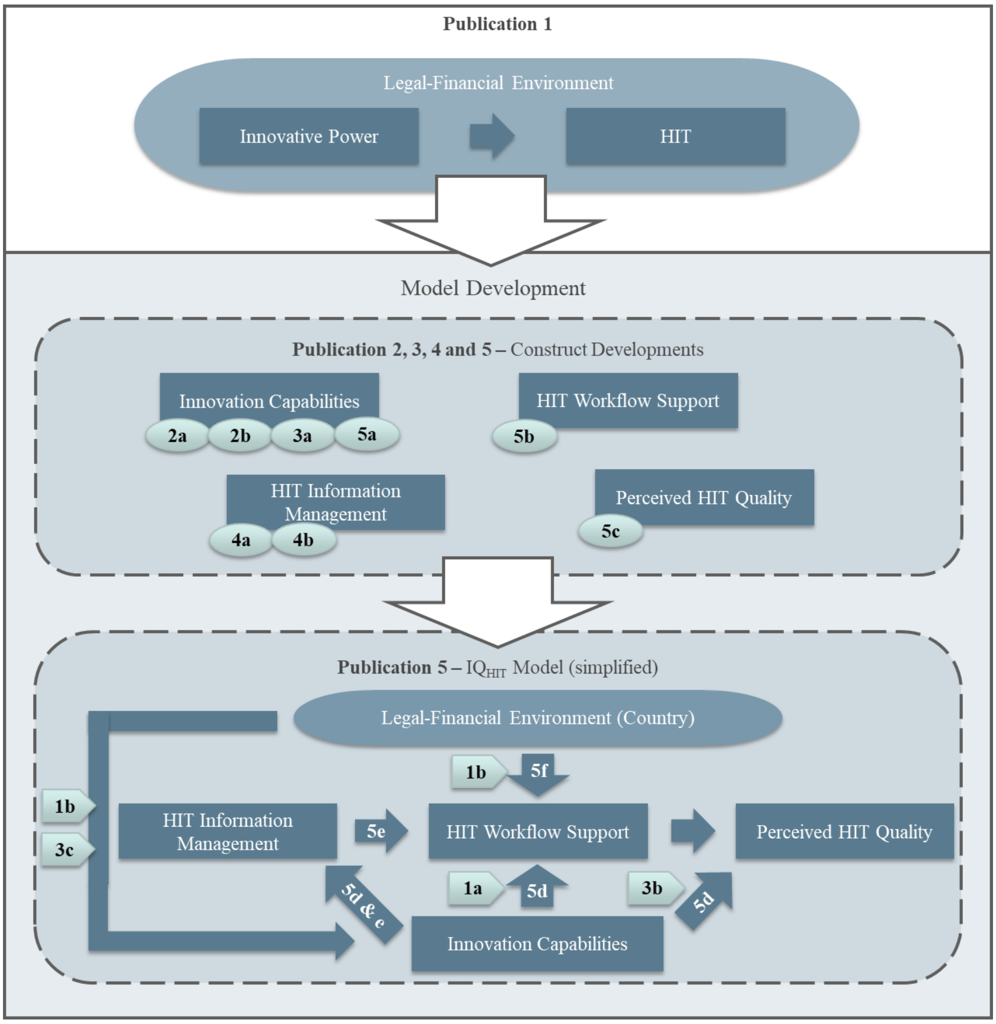

Figure 7: Numbered findings and contributions from Table 6 integrated with the overall results across the publications. Elliptical edges indicate findings that relate to the construct developments. Pentagonal arrows indicate findings that informed the structural model specification in Publication 5, and the numbered normal arrows indicate additional findings on associations in Publication 5.

All of these findings from publications 1-4, along with additional theoretical assumptions from the literature, guided the structural model's specification in Publication 5 (Figure 7). The resulting IQ_{HIT} model mostly confirmed the assumptions regarding the interrelationships between the corresponding constructs and particularly highlighted the mediating role of professional information management between the innovation capabilities of the top management team and the IT department on the one hand and the HIT-based workflow support on the other hand. The model also confirmed that the legal-financial environment influences the innovation capabilities and the degree of HIT-based workflow support, as Austrian and Swiss hospitals scored higher in these domains compared to German hospitals. Overall, the IQ_{HIT} model points to various relationships between the investigated constructs, not only based on the 17 hypotheses but also on the various total and indirect effects that follow from how those hypotheses were interlinked in the structural model. The corresponding results can be used as access points for further scientific inquiry and for deriving practical recommendations, both of which are discussed in the following sections.

5.2. Findings in Context

As previously outlined, the digital transformation in healthcare organizations holds promises for facilitating the paradigm shift toward learning health systems and precision medicine but also poses complex challenges for all stakeholders involved. By taking an interdisciplinary approach that draws on theoretical knowledge from the disciplines of health informatics, implementation research, information systems research, sociology, and management research, the IQ_{HIT} model offers unique insights on how some of those challenges might be overcome on the meso-level by virtue of an innovation-friendly attitude across several organizational levels, coupled with professional information management practices. Considerable portions in the variation of key constructs of HIT quality, such as the HIT workflow support and the perceived HIT quality, could be explained by the model as reflected in the corresponding R^2 values. The following sections discuss how the results contribute to the existing body of knowledge (chapter 5.2.1) and reflect on the core components and their interrelationships in greater depth at the meso-level (chapter 5.2.2 and chapter 5.2.3) and the macro-level (chapter 5.2.4).

5.2.1. The IQ_{HIT} Model: Positioning in the Theoretical Context

In terms of Heinsch et al.'s (2021) interpretation of Sovacool and Hess' (2017) typology of theories of sociotechnical change, the IQ_{HIT} model's basic premise and core findings resonate with structure-centered theoretical assumptions as it emphasizes the organizational and macro-level environment as determinants of HIT quality – as opposed to people's individual beliefs, attitudes, and actions in relation to innovation capabilities or HIT quality.[21]

In this space, it is the first of its kind in that no prior work has developed measures of innovation capabilities as a latent phenomenon that reflects the organization's ability to allow space for

[21] It should be noted that some scholars view organizations themselves as agents (Sovacool and Hess 2017), even though they are not individuals (who agency-centered theories typically focus on). Thus, it might be contended that the results indeed resonate agency-centered theoretical frameworks in that they highlight the agency healthcare organizations have in shaping HIT quality in comparison to the legal-financial environment which exhibited slightly smaller effect sizes across the model.

creativity, agility, and communication concerning IT-based innovation and integrates them with comprehensive measures of HIT quality that include a multitude of manifest measures relating to HIT functions, data availability, data integration and distribution. On top of that, the model includes known structural facilitators of HIT adoption, such as the organization's size and teaching status, and is unique in considering the legal-financial environment by including data from different countries. None of the empirical models referenced in chapter 2.2.3 that address similar research questions (Faber et al. 2017; Leidner et al. 2010; Paré et al. 2020; Erlirianto et al. 2015; Parthasarathy et al. 2021) cover such a variety of factors in one model or use similarly comprehensive measures.

This could be due to the fact that these models are based on a somewhat confined approach in their theoretical underpinnings: Leidner et al. (2010) exclusively draw on theories from management research, Faber et al. (2017) on information systems and management research (primarily the TOE Framework and the RBV), Paré et al. (2020) on information systems research and Erlirianto et al. (2015) exclusively on the HOT-Fit Framework. Parthasarathy et al. (2021) draw on a slightly broader range of theoretical considerations from information systems and management research and point to the necessity of addressing the healthcare specificities in this line of research. However, they fall short of translating this into measures of organizational innovation capabilities that actually encapsulate its different expressions[22] and also do not use manifest measures of HIT workflow support in their empirical work.

Corresponding to the limitations of such confined theoretical foundations, it was argued that the preexisting theoretical frameworks described in chapter 2.2.2 by themselves do not offer an appropriate level of precision or corresponding measurement tools to specifically investigate the relationships between innovation and quality in the context of HIT. Thus, the IQ_{HIT} model draws on various disciplines, resonating elements from several frameworks:

- Its fundamental sociotechnical orientation from the **Sociotechnical Systems Theory**: The results underscored the need for *joint optimization*, i.e., healthcare organizations need to consider the social systems (in this case, social systems that exhibit an inclination for HIT innovation) and technical systems (in this case, HIT systems) concurrently. However, STS theory often assumes reciprocal interdependencies between technical and social systems (Bostrom et al. 2009) which could not be recognized in the directional structure of the IQ_{HIT} model due to statistical constraints in PLS-SEM. Still, such reciprocities might exist between innovation capabilities and HIT quality.
- The importance of "inner" organizational shared values and routines as alluded to in **Institutional Theory**, the **RBV** as well as in the **CFIR**: Overall, the model parameters point to a more substantial predictive power of the capabilities of healthcare organizations (in terms

[22] While their theoretical elaborations on organizational innovation capabilities indeed resonate with how the construct is understood and operationalized in this thesis, the question items they use for measuring it only refer to very broad and outcome-orientated statements on innovation such as "The degree of process innovation in the organization is high.".

of innovation capabilities and information management) as compared to the influence of the legal-financial environment on HIT quality. Although the sustainability of these results across different legal-financial environments cannot be conclusively determined from this thesis, the emphasis on the inner organizational environment resonates with the fundamental tenets of the RBV and institutional theory. The CFIR does not make assumptions about the relative balance between the influence of inner and outer factors but still views the internal organizational capabilities as an integral part of any implementation success. The IQ_{HIT} model mirrors these frameworks' tenets but explicates them in more specific findings.

- The interplay of technological, organizational, and environmental factors from the **TOE Framework**: Even though the model does not strictly follow the original framework's specification (Tornatzky and Fleischer 1990), its fundamental tripartite lay at the foundation of the conceptual model and the empirical results underscore its usefulness. Particularly the environmental dimension (which is also picked up by the CAF as the "macro dimension" and in the CFIR as the "outer setting") as expressed by the inclusion of the legal-financial environment in the IQ_{HIT} model adds a valuable perspective as this introduces greater robustness to the results and yields additional insights.
- The importance of the organizational capacity to innovate referenced in the **NASSS Framework** for HIT in particular and in Rogers` **DoI** more generally: Greenhalgh et al. (2017) theorize organizational issues, particularly the capacity to innovate and readiness for technology, as one of the principal domains determining successful HIT implementation but do not go into details on how exactly they are expressed. They also build on the notion of complexity principles (Plsek and Greenhalgh 2001) by proposing that all of the framework's domains (condition, technology, value proposition, adopters, organization, wider system, and embedding and adaptation over time) can be classified as either simple, complicated or complex. It is contended that interventions characterized by high degrees of complexity in multiple domains are difficult to implement or even at the risk of failing. Contextualizing the IQ_{HIT} model in this framing offers a potentially useful insight: Especially the WCS reflects HIT systems of extraordinary high complexity (Hübner 2015) in an adopter system that also exhibits high degrees of complexity (i.e., hospitals as expert organizations containing multiple professions, departments, and complex workflows). In Greenhalgh et al.'s reading, this would imply a high risk of failing to achieve HIT quality, but the IQ_{HIT} model suggests that information management practices powered by organizational innovation capabilities might act as a counterforce for coping with this complexity. Seen through this lens, the model not only specifies what it means for an organization to be capable to innovate but also suggests that some NASSS domains might be able to offset the risk associated with high complexity in others.

Yet, a definite attribution to one of the theoretical frameworks is neither possible nor appropriate for fully addressing and contextualizing the research questions. Instead, the IQ_{HIT} model draws its advantageousness from an interdisciplinary positioning that informs and complements the theoretical body of knowledge from various angles: From the broader viewpoint of implementation research, its most significant contribution probably lies in the introduction of information management practices to the understanding of implementation success. Information management issues find better recognition in the literature on information systems research which, in turn, lacks a proper acknowledgment of the unique peculiarities of healthcare technologies. However, taking a context-sensitive approach toward HIT research is viewed as critical by many (Chiasson and Davidson 2004). In contrast, pertinent research from the field of health informatics has produced more elaborate concepts for the measurement of HIT quality measures and digital maturity (Carvalho et al. 2016) but is said to suffer from rather limited incorporations of sociotechnical perspectives (Parthasarathy et al. 2021) which the IQ_{HIT} model counteracts by drawing on sociological frameworks, namely the STS theory and institutional theory. However, the most significant contribution to both information systems research and health informatics lies in displaying the constituents and measurements of organizational innovation capabilities and how they affect HIT quality through information management practices. This finding has not been demonstrated empirically in either field before this thesis. Finally, from a management research perspective, the model reinforces the view that particularly the management team harbors significant degrees of power, even in strongly regulated market environments such as healthcare.

However, the model's theoretical implications are limited in some regards. For one, it was developed in a health informatics context and predominantly addresses challenges specific to the digitalization of healthcare organizations. It can, therefore, not necessarily be assumed that the model's key findings apply in the context of other industries or with regard to different outcome parameters. It also precludes individual, micro-level factors such as clinicians' trust, behavioral issues, expectations, and attitudes towards HIT, which lay beyond the scope of this work. Furthermore, there might be inherent limits to the IQ_{HIT} model regarding its predictive power when taking a contingency theory perspective. Contingency theory essentially poses there to always be individual and unique factors at play in organizational issues that are context-dependent and difficult to generalize (Fiedler 1964). In this view, organizations sometimes have to react to specific situations in specific ways that tend to defy standardized models. For instance, key HIT opponents in an organization who exert power at critical hierarchical junctures in an otherwise innovation-savvy organization (e.g., chief physicians or high-level managers) could compromise several of the proposed organizational mechanisms. These are situations where context-dependent management approaches (such as the ones discussed in chapter 2.2.1.) typically come into play as they usually aim to cater to the respective contingencies of varying organizational or environmental circumstances. Thus, it should always be expected that at least some variation in key domains remains unexplained beyond the measurement error variance. That is why it is recommended that HIT evaluations should generally not solely rely on standardized measurements like the ones proposed in this thesis but also be flanked by formative evaluation approaches using qualitative methods (Cresswell et al. 2020). For the IQ_{HIT} model, this means that context-dependent management approaches could thus be viewed as complimentary to the model's conclusions as to the universally applicable value of developing innovation capabilities and information management practices.

All in all, the IQ_{HIT} model fills a gap in the theoretical knowledge on what drives HIT quality on the organizational level and provides various access points and measures for further research in the field of health informatics as well as in the adjacent disciplines.

5.2.2. HIT Quality

HIT quality is used in this thesis as a term to describe a concept and measurement framework for expressing various key components of what comprises high-quality HIT systems. Most notably, this includes information management practices, HIT workflow support, and perceived HIT quality. These elements could be thought of as fundamental cornerstones and prerequisites for the digital transformation in healthcare organizations. In the understanding of the IQ_{HIT} model, they depend on each other along the path from information management to the perceived goodness of information provision for patient care.

Previous conceptions of HIT quality that go beyond the mere focus on IT adoption measures – which is the default in most digital maturity models (Carvalho et al. 2016), such as EMRAM – are scarce. The CAF (Lau et al. 2011) is one of the few frameworks that explicitly picks up on the notion of HIT quality, adapted from Delone and McLean's (2003) IS success model's distinction of information quality, system quality, and service quality. Their definition of HIT quality primarily comprises the availability of clinical information content, the HIT system's features, and the service quality in terms of support from the IT department (Lau and Price 2017). While this is congruent to key elements of how HIT quality is defined and measured in this thesis, it is specifically lacking a broader view of information management beyond IT support, a conceptualization of how those elements are interlinked, and also underemphasizes the HIT systems' process orientation which is considered to be essential for HIT to be used effectively (Lenz et al. 2012; Walker and Carayon 2009).

Characteristics and Interconnections

Whereas the first publication used a subset of items on HIT that make up the descriptor "function" of the workflow composite score, the following publications expanded on this by adding measures of the perceived HIT quality (Publication 3 and 5), information management (Publication 4) and eventually a fully revised WCS along with the former two in Publication 5.

The use of the WCS as a measure of the HIT workflow support that does justice to the complex nature of interdepartmental and multifunctional health information systems lies at the core of the IQ_{HIT} model and is one of its most important strengths. It makes it stand out against the majority of

HIT adoption studies which tend to focus on specific systems or applications. The score's process orientation is expressed in that all descriptors (data and information, IT functions, integration, and distribution) that structure the scoring are measured along core clinical workflows: the admission process, ward rounds, pre- and post-surgery workflows, and the discharge process (see Figure 6 in chapter 3.3.1). Although the development of the original structure of the WCS dates back to 2015 (Liebe et al. 2015), it was substantially revised for this thesis by adding the admission process along with corresponding items, by adding items to correct for the underrepresentation of the descriptor integration which was identified in earlier validation work on the WCS (Esdar et al. 2017), the incorporation of additional functions such as telemedicine, and by the application of a new weighting scheme. The resulting score comprises 146 question items and can be classified as a digital maturity model for hospitals, which is considered to stand out for its process orientation (Burmann and Meister 2021). On average, the hospitals in the dataset scored 56 out of a possible maximum of 100 points with a standard deviation of 14 points (see Appendix Table 3 of Publication 5) which corroborates findings from other sources that suggest a mediocre degree of HIT workflow support in German hospitals (Sabes-Figuera and Maghiros 2013; Stephani et al. 2019). It also confirms that the degree of HIT workflow support varies significantly between individual organizations.

The IQ_{HIT} model suggested that the WCS is strongly influenced by the professionalism of information management (PIM) (see also Figure 8). Based on the notion of the Japanese-German quality requirements framework of EHRs (Winter et al. 2017), PIM can be considered part of what makes for a high-quality HIT system and is therefore treated as an integral part of HIT quality. On average, PIM also showed a somewhat mediocre score value of 65 out of 100 points (see Table 6 in Publication 4), and the results reflected considerable differences between organizations, with a standard deviation of 19 points. To the author's knowledge, these are the first and only quantitative findings on the professionalism of information management and the work of IT departments in Austrian, German, and Swiss hospitals and their influence on HIT measures.

The relationship between PIM and the WCS seems to be mediated by the use of clinical IT agents in the organization which expresses the importance of anchoring participatory elements in the organizational information management structures for promoting HIT workflow support. This is a finding underscored by several studies that point to the need to systematically bridge clinical and technological requirements through better participation of clinicians in HIT management and use (Fennelly et al. 2020; Liebe et al. 2018; Sligo et al. 2017). The value of the exchange of clinicians with the IT department also resonates with the findings of Publication 3. Here, the satisfaction of clinical directors with the exchange with the IT department was positively associated with the degrees of the overall goodness of information provision in the care processes.

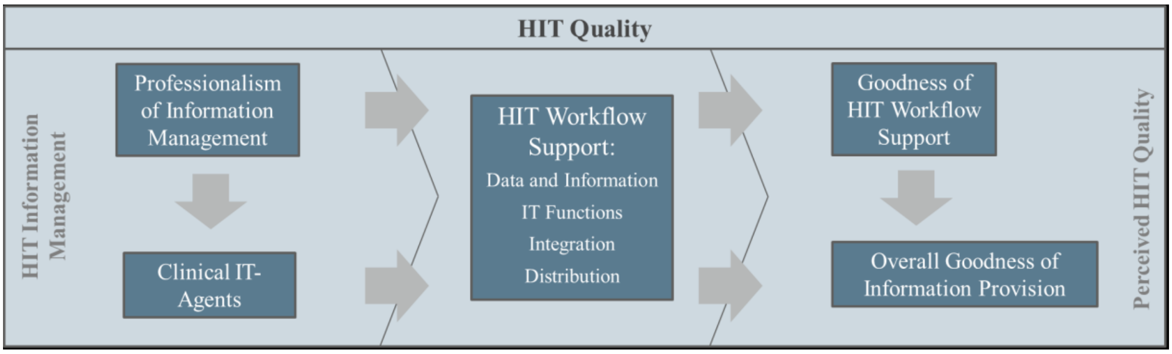

Figure 8: HIT quality constructs and their interrelationships.

HIT support for patient care may have objective and subjective parts. This was conceptually acknowledged by distinguishing the HIT workflow support as a somewhat objectified and factual component of HIT quality from a perceived component that ultimately bundles the understanding of HIT quality. The CIOs judgment on the overall goodness of information provision (OGIP) was found not to be directly linked to the more objective facts (e.g., the availability of specific functions or data) of the HIT workflow support but appeared to require some intermediate interpretation, i.e., the perceived goodness of HIT workflow support. The latter was evaluated in closer correspondence to the WCS based on five grading scales of how well the HIT systems support the five clinical processes (admission, ward rounds, pre- and post-surgery, discharge) and included as a reflective measurement model whereas the overall goodness of information provision was a single-item construct.

These discrepancies between the HIT workflow support and the perceived HIT quality might also be construed in light of the unintended consequences and adverse effects HIT systems can evoke. It is not guaranteed that higher degrees of digital maturity, even when conceptualized and measured in the context of clinical workflows, unequivocally lead to better information provision as perceived by clinicians. Issues like poor usability, faulty system features, excessive data entry requirements, or information overload can compromise successful information provision and even harm clinicians' mental well-being (Kroth et al. 2019; Colicchio et al. 2019). Controlling for these factors, however, lay outside the scope of this thesis. Yet, Eschenroeder et al. (2021) recently found that clinicians who believe that their organization has done a great job with HIT implementation, training, and support were less likely to report burnout symptoms compared to those who believed otherwise. These factors are indeed reflected in some of the measurement scales for professional information management and innovation capabilities and appeared to contribute to the perceived HIT quality.

However, the relationships in this part of the model reflecting the perceived HIT quality require further research and validation. Unlike PIM, the IT department's innovation capability, and the contents of the WCS, the perceived HIT quality could also be evaluated from the perspective of clinical end-users, which might offer additional insights. However, this approach was not feasible in the context of this thesis. Also, the perceived HIT quality might be an essential cornerstone of HIT quality, but eventually, research efforts will have to increasingly shift towards the question of how HIT quality affects patient outcomes. The evidence on this is still mixed (Williams et al. 2016; Martin et al. 2019), and the evaluation of complex HIT systems on this level is difficult, which might require different research designs, including formative and qualitative evaluation elements (Krasuska et al. 2021).

5.2.3. Organizational Innovation Capabilities

Research on HIT quality in the past has frequently disregarded aspects of innovation, and both have often been discussed separately (Hübner 2015). One of the main results this thesis yields is the proposal of various scales on organizational innovation capabilities resulting from Research Question 1 and showcasing their predictive usefulness for measures of HIT quality resulting from Research Question 2. Before this thesis, there were loose indications that the capacity to innovate and related concepts might be vital precursors for successfully building HIT systems (Allen et al. 2017; Cresswell et al. 2017; Greenhalgh et al. 2017), but no validated measures existed to test corresponding assertions empirically. The scales were developed across three separate datasets that each contained variations and extensions based on the respective previous findings and depending on each survey's target respondents (see chapter 3.3.1 for details on this iterative procedure). The following section discusses the constituents and measurements of organization innovation capabilities (corresponding to Research Question 1) and the influence of such capabilities on HIT quality (corresponding to Research Question 2).

Constituents and measurements of organizational innovation capabilities

Good leadership with the willingness to innovate, creativity, openness towards innovation, future orientation, proactive behavior, risk-taking, and communication were among the most frequently occurring elements of what might constitute organizational innovation capabilities in the OECD's Oslo Manual (OECD 2018), the NASSS Framework (Greenhalgh et al. 2017) as well as in the works from Lynch et al. (2010), Ruvio et al. (2014), and Patterson et al. (2009). All of those elements were taken into account during the development of the scales, but the resulting measurement models are unique in two ways at least. First, they are specifically tailored towards HIT-based innovation in healthcare organizations. Secondly, they clearly suggest that distinctions should be made according to what organizational level or subgroup the innovation capabilities refer to. Large healthcare organizations such as hospitals consist of multiple departments, professional groups, and hierarchy levels that might exhibit varying degrees and elements of such capabilities. This complexity was acknowledged by including items that refer to different organizational levels and by reflecting on the topic from two different viewpoints: from the CIO's perspective (Publication 2 and 5) and from the clinical director's (Publication 3).

In the final scale set, the innovation capabilities of the top management team are expressed as a distinct latent variable which is reflected in an executive board that actively promotes and explicitly calls for innovative HIT solutions, pursues a well-defined vision, does not perceive HIT as mere expense factors, and also seeks a close exchange with the CIO – thus mirroring the abovementioned leadership qualities with regard to openness towards innovation, future orientation, proactive behavior, and communication. The element of creativity found expression on the level of the IT department, where innovation capabilities manifest themselves in virtues pertaining to the teams' sense of cohesion, high degrees of creativity coupled with higher degrees of employee autonomy, and close communication and collaboration with the clinical users. This measurement model slightly differed from its corresponding factor found in Publication 3 (labeled as "Exchange with IT department"), which was evaluated from the clinical directors' perspective. The respective items in this factor reflected various elements of the communication and collaboration with the IT department from the clinicians' viewpoints. Thus, while these two constructs should not be regarded as the same, they do reflect two sides of the same subject, i.e., complementary viewpoints on the IT department from the inside (CIO) and the outside (clinical directors).

Lastly, the abovementioned element of responsiveness is expressed in the construct that reflected items referring to the entire organization in terms of its flexibility, agility, responsiveness, the absence of a general IT aversion, and, again, open communication among all the staff on IT issues.

Only the element of risk-taking, which was frequently cited in previous definitions of what enables an organization to innovate (e.g., Ruvio et al. 2014), was dropped during the course of refining the measurement models as there was only one question item referring to this which turned out not to show any conceptual overlaps with other items (i.e., had low factor loadings with all three constructs). This does not imply that risk-taking should be discarded but rather that it might be indicative of a distinct construct that would require more redundancies (i.e., expressions of risk-taking) in future scale sets.

Across the publications of this thesis, the underlying structure of the components reflecting organizational innovation capabilities changed slightly. This was mostly due to the fact that greater differentiation in the form of additional items was introduced in the later surveys based on the previous results and that the item set was slightly adapted to accommodate the viewpoint of clinical directors in Survey 3. Yet, the variations in the innovation capability domain's structure also suggest that it might change further in light of additional data and new items as there remains a considerable conceptual overlap between the final three sub-components identified in Publication 5. Nevertheless, thinking about innovation capabilities as a phenomenon that exhibits different expressions on different organizational levels, especially regarding these three levels presented here, adds to its conceptual understanding and informs future research. All in all, the results offer a specification for a construct that had been poorly developed before and, therefore, informs theoretical frameworks like the NASSS, which alluded to this domain but left it vaguely defined.

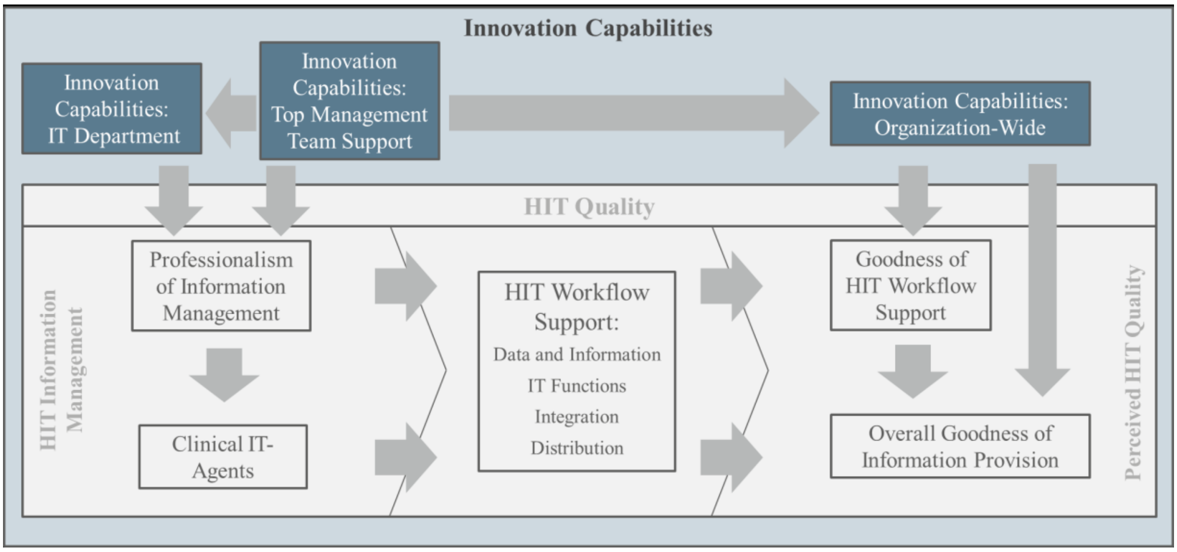

Figure 9: Innovation capability constructs and their interrelationships.

The Influence on HIT Quality

Publication 3 revealed a significant influence of the executive-level innovation capabilities on the overall goodness of information provision.[23] Drawing on this finding, the IQ_{HIT} model in Publication 5 suggested a more refined picture of how this association could be explained: According to the estimated total effect (Appendix Table 7 from Publication 5), the innovation capabilities of the top management team again showed a significant effect on the overall goodness of information provision. However, this effect was mediated through various channels. Drawing on premises from the Upper Echelon Theory and bolstered by the repeated finding of the importance of top management support for the overall climate on HIT (Abdekhoda et al. 2015; Leidner et al. 2010), the model was specified in a way that hypothesized that the innovation capabilities of the TMT can radiate across other organizational levels – In this case, affecting the IT department and the organization at large (Figure 9). This was confirmed by the model estimation which showed that about one-third of the variation in the respective variables could be explained by the innovation capabilities of the top management team.

With regard to the relationship to HIT quality, one of the most crucial contributions of this thesis, particularly to the field of health informatics, is the finding that the professionalism of information management strongly mediates the influence of the innovation capabilities of the TMT and IT department on the HIT workflow support. This offers a clear explanation as to how exactly innovative healthcare organizations can translate attitudes and intentions towards HIT innovations into higher degrees of HIT-based workflow support. Although this finding is unique in the healthcare context, it at least partly corroborates assertions derived from the research of Jansen et al. (2006), who suggested that the higher degrees of formalization of management practices are predictive of process innovation in the financial service sector.

[23] Referred to as „clinical information logistics" in that publication.

Furthermore, the results showed that organization-wide innovation capabilities might be an important trait for enhancing the perceived HIT quality irrespective of the factual degree of HIT workflow support, as they directly influenced the perceived HIT quality and exhibited no association with the WCS (Figure 2 in Publication 5). This could be interpreted as an indication that an organization-wide positive attitude toward using the IT in place, however advanced it might be, leads to better perceived information provision in the clinical care processes – at least from CIOs' vantage point.

Greenhalgh et al. (2017) suggest that the organizational capacity to innovate also requires “slack resources”. While this was not conceptualized as an integral part of innovation capabilities, it was still taken into account in the IQ_{HIT} model by including a formative construct composed of the hospital size (bed count) and teaching status. Both can be understood as indicators of slack resources in terms of greater financial and human resource flexibility, and both typically are associated with higher degrees of HIT adoption (Kruse et al. 2014; DesRoches et al. 2012). The results indeed showed that this had a positive effect on the workflow composite score, but it was entirely mediated by the innovation capabilities of the top management team and by the professionalism of information management. This is surprising since no prior research had provided empirical explanations for how larger and teaching hospitals reach higher HIT adoption rates. It appears like they might do so by employing top managers who seek innovation and by investing in their information management activities.

Although the literature on change management should be approached with some caution, these results on the role of organizational innovation capabilities could further be contextualized and researched using Weiner’s (2009) Theory of Organizational Readiness for Change. He argues that an organizational culture that embraces innovation could be seen as a distinct and broader contextual condition that might generally affect change management capabilities. Following that logic, it might be worthwhile for future research to consider developing the innovation capability constructs towards greater independence of HIT-related issues to predict multiple types of innovation in health care. However, this was not a sensible first step in this line of research since this thesis focused on how to build high-quality HIT systems in particular. Furthermore, the consideration of a more general notion of organizational innovativeness would have also carried the risk of making type II errors, i.e., measuring innovativeness that, in the eye of the respondent, relate to other issues (e.g., surgery techniques, new modes of healthcare delivery, etc.) and might have turned out not to be predictive of HIT quality. Correspondingly, in discussing measurement issues for his theory, Weiner (2009) argues in favor of scale sets that are tailored for specific organizational changes rather than generalized items.

In summary, the results repeatedly underscored the power of the organizational capabilities to innovate and digitally transform their care processes across three separate surveys (Publication 1, 3, and 5) and paint a clear picture of how such capabilities influence HIT quality in conjunction with information management practices.

5.2.4. Legal-Financial Environment

Evidently, the organizational capabilities on the meso-level play a vital role and explain the variation in HIT quality across hospitals to a large extent. But not least to reach universal information continuity across all care settings, it also requires a legal-financial environment on the macro-level that facilitates HIT. Furthermore, directed governmental interventions to shape this environment from the top-down have shown to affect HIT adoption in healthcare organizations (Kim et al. 2017; Liang et al. 2021; Esdar et al. 2019) – albeit with varying success in different countries (Ammenwerth et al. 2020). Therefore, both HIT quality and innovation capabilities were conceptualized to be shaped by the legal-financial environment per Research Question 2.

To operationalize this influence, all surveys (except for Survey 2 used in Publication 2) included data from multiple countries with different legal-financial environments, i.e., Germany, Austria, and Switzerland (the latter only in Survey 3 and 4). However, more detailed measures of the legal-financial environment and its different facets are clearly conceivable, and other research designs like qualitative approaches (Naumann et al. 2021) or longitudinal assessments (Holmgren et al. 2017) can yield more detailed insights. Still, all hospitals in the respective countries were subjugated to the same legal framework at the time of data collection, which gives some indications about this environmental influence when comparing the measures of innovation capability and HIT quality across countries.

The respective results yielded two insights: First, it showed that Austrian and Swiss hospitals exhibit higher levels of HIT quality in various ways, confirming the legal-financial environment's influence: Results from Publication 1 demonstrated that Austrian hospitals had higher adoption rates of HIT functions (particularly nursing documentation systems, ICU documentation systems, and medication management systems). Publication 3 showed that clinical directors of Austrian and Swiss hospitals rated their overall goodness of information provision (i.e., clinical information logistics) significantly higher than their German colleagues did. Finally, Publication 5 confirmed these results from the CIOs' perspective in that the country variable (representing Austrian and Swiss hospitals) had a significant total effect on the same variable (see Appendix Table 7 from Publication 5). Furthermore, it was also confirmed in Publication 5 that the country differences did not only apply to the perceived overall goodness of information provision, but also to the HIT workflow support according to the significant direct path coefficient between the country variable and the WCS (see Figure 2 from Publication 5). At the time of data collection, Austria was amidst introducing the ELGA record system, and Switzerland started implementing the EPD. In contrast, Germany still struggled with building the basic infrastructure for electronic health data exchange (called the "Telematikinfrastruktur") and only had unspecific plans for implementing a large-scale electronic health records system for their citizens. Crucially, Germany was not yet supporting the adoption of HIT systems in the hospital sector, and many hospitals were under significant financial pressure, which hampered the adoption of HIT systems (Esdar et al. 2019). These findings cannot conclusively ascertain whether the ELGA and EPD initiatives were responsible for the differences, if Austrian and Swiss hospitals just had more financial leeway or if other factors were at play, which is discussed elsewhere (Naumann et al. 2019). Nevertheless, the legal-financial environment certainly had some bearing on HIT quality as these country differences were replicated across surveys.

Differences between Germany and Austria concerning HIT in general were not entirely surprising in the light of previous findings (Hübner et al. 2010). More surprisingly, however, was the second key insight, i.e., that these differences appeared to be not limited to HIT quality measures but, in fact, also applied to organizational innovation capabilities. Results from Publication 3 suggested that the collaboration with IT departments was better in the Austrian and Swiss hospitals compared to Germany. Building on this finding, the IQ_{HIT} model confirmed that the innovation capabilities of the IT department and the organization at large were affected by the country. This might point to a more systematic issue in German hospitals regarding how HIT innovations are perceived, communicated, and managed, but it also offers potential levers for managing HIT in healthcare organizations.

Despite these effects, the organizational "bottom-up" forces showed larger effect sizes and contributed more to explaining the variation in HIT quality in the IQ_{HIT} model. This shows that, while the legal-financial environment matters, the varying organizational capabilities should not be underestimated in the context of future HIT policies. However, the balance might shift when other countries are included in the analysis that employed more decisive measures to incentivize HIT as the US did from 2009 onwards. It could also be argued that the German KHZG (which was passed after the empirical work of this thesis) has fundamentally changed the incentive structure and now largely dictates the internal IT strategies in German hospitals (Meier et al. 2022). Thus, the relative influence of the legal-financial environment on HIT quality might have increased for them, suggesting that the IQ_{HIT} model's parameter might generally change over time when new samples are drawn. However, Cresswell et al. (2021) recently argued in a commentary on the IT policies in the NHS that "there is a need to realise that digital transformation is a marathon, not a sprint, and, indeed, a journey with no endpoint" which highlights the need for ongoing digitalization efforts by healthcare organizations beyond the limited timeframes of incentive programs like the KHZG. Also, in light of continuing technological innovations, "being digital" should be conceptualized as a moving target (Frennert 2021) that likely requires ongoing and persistent innovation-seeking behavior and capabilities from healthcare organizations, irrespective of different or changing legal-financial environments.

Nevertheless, the IQ_{HIT} model should be tested and refined in the context of different political settings and at other points in time to solidify its validity. Still, including this view provides a greater degree of robustness to the results as it reduces the risk of observing relationships that are unique to one country. This enhances its potential applicability across various countries. To the author's knowledge, no prior empirical model on HIT quality or related topics on the organizational level has controlled for the legal-financial environment's influence on objective grounds by using international datasets and can make similar claims.

5.3. Implications and Recommendations

The IQ_{HIT} model and the interim results leading up to it implicate various practical recommendations for managing healthcare organizations on the meso-level and for policymakers on the macro-level.

Implications for the Management of Healthcare Organizations

Most importantly, managers need to be aware that attaining higher degrees of HIT quality in one's organization should be viewed as a fundamentally active rather than passive venture, and it requires initiation and support from the top management team. Proposing a vision for the HIT system, promoting it, and nurturing a climate that is open to HIT-based innovation and active communication about this are the precursors of successful HIT use. While national policies from the "top-down" can determine HIT adoption rates to some extent, the top management team still holds a significant degree of power that goes beyond influencing the mere adoption. Striving for HIT quality also requires managerial attention to the IT department and information management practices. Just like in the top management team, managers should try to build IT departments that provide space for creativity and closely collaborate with clinicians. Moreover, they should regularly make sure to conduct and facilitate the information management procedures and activities described in PIM. This research did not focus on how innovation capabilities can be built. However, having the *right* management and IT staff would certainly be helpful. Therefore, the virtues reflected in the innovation capabilities scales should be selected for in the recruitment processes of new IT staff. Furthermore, the managerial procedures and practices reflected in PIM, as well as the expressions of innovation capabilities, should be picked up by professional development and education programs for managers (e.g., focusing on their awareness for HIT based innovation and the ability to encourage their teams effectively), IT staff (e.g., focusing on creativity, communication, and interprofessional collaboration), and clinicians (e.g., focusing on awareness for digital innovations and their effective implementation).

Overall, managers should be aware of the organizations' critical translational function of bringing HIT innovation into clinical workflows and should address the digital transformation not as a mere technical but as a sociotechnical challenge. The IQ_{HIT} model provides various access points as to how this could be approached.

Policy Implications

Policymakers also need to understand this notion of the digital transformation as a sociotechnical challenge. They need to be aware that HIT-based innovation can only be prescribed from the top-down to a certain extent and have to largely be promoted and managed from within the organizational context. This implies for them to not just blindly incentivize technology adoption but to instead be aware of the intermediate steps on the path towards better HIT quality and to be sensitive to the organizational context. In practical terms, this could translate to (1) helping to ensure that capable management teams lead healthcare organizations, (2) making sure that the organizations' innovation capabilities are not compromised by an overflow of new regulatory requirements at once, (3) supporting the education and development of the healthcare organizations staff, and (4) focusing on the clinicians' perception of HIT workflow support rather than exclusively relying on HIT adoption measures when setting up policies and incentive programs.

Such issues could specifically be addressed by providing complementary investments. These are investments that go beyond subsidizing or financing the technologies alone (e.g., licenses, hardware, infrastructure) but consider specific complementarities such as frontline user training or the size and composition of the management team, as Holmgren et al. (2021) have similarly suggested in the context of researching organizational IT strategies. Particularly in the German healthcare system, investments in interdisciplinary IT teams should be considered. The IT team carries out most of the operational work to digitize care processes, and IT professionals are in high demand in the labor market. This demand has already led to a shortage of skilled professionals (Ärztezeitung 2020). Complementary investments could materialize in the form of mechanisms to ensure higher IT budgets, which are particularly low in German hospitals (Günther and Braun 2020).

Furthermore, policymakers should pay attention to the structural characteristics that healthcare organizations cannot fundamentally change but which are correlated with higher degrees of HIT quality, like their size and teaching status. Larger organizations, and those who have a stronger focus on research and teaching, attain higher degrees of HIT quality, and this needs to be factored in when making decisions about the macro-level care delivery structures so as not to risk creating a “digital divide” between organizations (Adler-Milstein et al. 2017).

Policymakers should also consider supporting future research on organizational facilitators of HIT and HIT-related outcomes – especially research designs that allow for identifying causal relationships. While suitable research designs are very challenging and costly for complex HIT interventions due to difficulties in randomization as well as in finding viable controls, quasi-experimental studies using econometric methodologies might be feasible – for example, by funding complementary investments on a time-shifted basis to different groups of organizations in order to use the non-exposed units as control groups. The regular collection of corresponding data (e.g., annually) is recommended to allow for time-series research designs. Policymakers frequently rely on digital maturity models to collect such data when evaluating macro-level incentive programs (Cresswell et al. 2019; DigitalRadar Krankenhaus Konsortium 2021). Hence, maturity models used for policy evaluations should be augmented with the measurement scales proposed in this thesis, particularly with regard to the innovation capability and information management constructs.

Implications for further research

The IQ_{HIT} model fills a gap in the theoretical and empirical literature with regard to the understanding of what constitutes innovation capabilities of healthcare organizations as well as the professionalism of their information management (Research Question 1) and how they affect HIT quality in various legal-financial environments (Research Question 2). Still, several research needs emerge from the findings. For one, the model should be validated to solidify its underlying constructs and their relationships. Secondly, while the model already exhibits high degrees of complexity in its structural specification, it should be further extended to attain a more comprehensive picture of the mechanisms that drive the digital transformation in healthcare organizations. To do so, several outstanding questions adjacent to the results of this work should be addressed in future research:

- *Is the IQ_{HIT} model replicable when tested based on new datasets?* Corresponding validation studies should assess (1) the model's reliability based on additional data from the CIO perspective, (2) its behavior when additional perspectives, such as the views of the CEOs and clinicians, are factored in to circumvent possible biases caused by common-method variance, and (3) how different legal-financial environments would affect the model parameters.
- *How do both innovation capabilities and HIT quality interact to allow for benefits realization through HIT, e.g., enhanced patient outcomes or efficiency gains?* For example, organizations with excellent innovation capabilities might not only be better at providing HIT-based workflow support but might also facilitate reaping the clinical benefits from such support. Despite that, the seemingly straightforward link between HIT quality and corresponding benefits realization by itself needs to be examined as evidence of quality gains through HIT is still mixed (Martin et al. 2019; Williams et al. 2016).
- *How can healthcare organizations develop their innovation capabilities, i.e., what are its predictors?* This research focused on what follows from having the organizational capacity to innovate, but not on what causes it. Further research on this would be a useful complimentary.
- *What role does the IT budget play?* The amount of funds available for IT is a major factor in influencing HIT adoption (Jaana et al. 2011; Hübner et al. 2018). It might also be linked to the organization's innovation capabilities and would probably help explain varying degrees of HIT quality. However, obtaining accurate information on the organizations' size of the IT budgets is challenging. Survey 3 included a corresponding item, but many respondents appeared not to feel comfortable sharing financial information (or simply did not know) and skipped the question, which is why it was not included in the analyses.
- *How do innovation capabilities and their effect on HIT quality relate to varying degrees of autonomy on an organizational or unit level?* In researching innovativeness at the level of hospital clinical units, Glover et al. (2020) found that higher degrees of autonomy might actually hamper innovation in units that exhibit high degrees of complexity. Although some aspects of autonomy were indirectly reflected in the innovation capabilities of the IT department, this topic should be expanded on as a potentially insightful moderator on several organizational levels.

- *Are there any non-linear relationships between the studied constructs?* Faber et al. (2017) found some indications for possibly non-linear relationships in their data, for example, between top management support and HIT adoption. It is conceivable that, for instance, hospitals with relatively high degrees of innovation capabilities can only realize reduced marginal gains in HIT quality, which could be put to the test in various ways.

Overall, the sociotechnical approach taken in this thesis, in combination with advanced statistical modeling techniques that comprise both latent and manifest organizational traits, provided the foundation for this work. From a statistical viewpoint, especially the application of PLS-SEM for identifying driver constructs in a complex structural model with variously specified measurement models was key to yielding the insights. The constraints of traditional covariance-based SEM would have not allowed for the same model specifications. Considering that the PLS-SEM method currently sees many further refinements and extensions (Sarstedt et al. 2022), which will likely further increase its accessibility and versatility, its application should be considered more regularly when addressing the above-mentioned research needs or pursuing similar research approaches.

5.4. Limitations

Next to the limitations noted in the respective publications, some superordinate limitations must be considered in the overall view concerning the research design, the methods, and content-related deliberations.

Research Design

Although this thesis used multiple datasets, it is an observational and fundamentally cross-sectional study. While this is innocuous for the analyses addressing Research Question 1, i.e., the factor analysis on innovation capabilities and PIM, it implicates epistemological constraints to interpreting the relationships found between the constructs (i.e., the analyses of associations relating to Research Question 2). Consequently, it cannot be contended that there are genuinely causal relationships between organizational innovation capabilities and HIT quality. Such inference would have required a controlled (quasi-) experimental design, which, however, is resource intense and not feasible on this level of multi-organizational research on complex HIT systems. Aside from issues relating to the overall design, it could have been beneficial to merge the perspectives of the CIO and the clinical directors and conduct the analysis on a combined dataset. While this was theoretically possible via the organization’s institutional identifier for Survey 3 and 4 as these two were collected around the same time, it was eventually dismissed since merging the datasets resulted in a sample that was too small. The analysis for fitting the IQ_{HIT} model would have been substantially underpowered. Nevertheless, the thesis included both perspectives, albeit in separate publications. The corresponding analyses might thus be prone to biases in terms of inflated R^2 values due to possible common-method variance as the dependent and independent variables were reported by the same person in Publication 1, 3, and 5, respectively. However, these drawbacks are somewhat mitigated by the fact that findings of several key associations between the constructs were replicated across publications. Still, validation studies should be conducted, as was noted above, and the results easily allow for such studies as much as they provide many suggestions for testing related hypotheses.

Furthermore, including qualitative data for contextualizing and bolstering the findings could have been useful. For example, such data could have provided additional insights for conceptualizing the different organizational characteristics that reflect innovation capabilities in relation to Research Question 1 or capturing elements contingent on specific circumstances in an organization in relation to Research Question 2. However, the primary goal was to assess whether a relationship between innovation capabilities and HIT quality could be observed systematically, i.e., from a population-level perspective, to avoid the risk of only reflecting individual circumstances that might not have been representative. Also, there was plenty of qualitative literature to inform the construction of the scale sets and for deriving the hypotheses, whereas few quantitative attempts to test such hypotheses had been made prior to this thesis. Incorporating qualitative research elements beyond the workshops and pretesting iterations conducted for the scale developments were thus not deemed necessary in light of resource limitations.

Methods

The statistical techniques utilized throughout this thesis largely reflect current best practices. However, some issues can be pointed out in the overall approach: The development of the PIM scales followed a very straightforward process per the guideline by MacKenzie et al. (2011), which was facilitated by the fact that there was a clearly predefined conception of how the construct would be structured (across strategic, tactical and operational management activities). For the innovation capability scales, however, the development process was less straightforward as several overlapping concepts needed to be considered and new items were added survey by survey, which affected the resulting factor structures. This was partly done to accommodate other viewpoints (especially the ones of clinical directors in Survey 3) but also based on previous findings, which were expanded on in the following survey. Also, the process could have been more concise if the innovation capability scales had only included the organizational and not the intrapersonal level. The personal innovation capabilities could be viewed as somewhat unnecessary baggage in the process of attaining a valid and reliable factor solution on the organizational level. The variation in the factor structures that emerged across publications might suggest that the components proposed in Publication 5 could be further developed and refined. However, this iterative, data-driven process allowed for exploring additional features during the development, and the final measures of discriminant and convergent validity estimated in the IQ_{HIT} model were satisfactory.

Regarding the specifications of the measurement models in Publication 5, it could be argued that the higher-order PIM model should have been specified as a formative rather than reflective construct since PIM consists of – or is formed by – its strategic, tactical, and operational sub-dimensions. However, this was not possible due to methodological restrictions in PLS-SEM since there still are no viable techniques to use formative models as endogenous variables in the structural model without compromising the path coefficient estimations.

It should also be reiterated that the legal-financial environment was only measured by including Austrian and Swiss hospitals as opposed to German hospitals in the analyses. While the country surely matters in shaping the legal-financial environment, and it certainly differs between countries, additional factors relating to federal or communal regulations and the shareholder structure should also be considered.

Model Contents

Complexity is one of the most challenging issues in researching organizational mechanisms. This also applies to this thesis as the methodological approach inherently limits the scope of topics and mechanisms covered in one model. There are plenty of additional perspectives, organizational layers, individual factors, more complex, and non-recursive relationships that could be considered in tackling the research questions. However, the approach in this thesis attempts to strike a balance between including as many potentially relevant organizational factors as possible in the analyses and keeping the solution handleable – both conceptually and statistically. For example, regarding the innovation capability scales, items relating to risk-taking and error culture had to be dropped in the development process to achieve better convergent validity in the measurement models.

The assessment of HIT quality through the lens of the CIO exclusively also comes with limitations. As alluded to above, the perceived HIT quality could also be evaluated as perceived by the front-line clinicians and analyzed using hierarchical modeling techniques. This, however, was not feasible in light of resource limitations for field access and data collection. Also, HIT information management and the HIT workflow support as a core element of HIT quality can only be evaluated from the CIO perspective as no other person in the organization could have been expected to be able to provide information on the numerous associated question items.

Lastly, the terminology usage throughout this thesis exhibits partial inconsistencies as some concepts are referred to by different terms across publications. Most notably, the variable that is referred to as “overall goodness of information provision” in Publication 5 is simply called “clinical information logistics” in Publication 3. The latter term refers to the underlying theoretical concept of what the question addresses, whereas the term used in Publication 5 is more descriptive. The change was made in Publication 5 to avoid including too many concepts in the IQ_{HIT} model so as to keep the models’ complexity comprehensible. Concerning innovation capabilities, it should be noted that at first, the term “innovative power” was used in Publication 1. However, based on discussions about the possible risk of tautological overlaps in the respondents’ evaluation of the innovative power on the one hand, and the availability of HIT functions on the other hand, it was decided that there needed to be a better conceptual delineation. As a result, the term “innovation capabilities” was coined as a more appropriate term to convey that it ought to be a condition that exists prior to HIT adoption and workflow support. Additionally, the term “socio-organizational factors” was used in Publication 3 to refer to innovation capabilities. Since the term did not convey any additional theoretical or conceptual assumptions and to simplify the terminology use in the IQ_{HIT} model, it was not picked up in Publication 5.

5.5. Conclusions & Outlook

Despite the many untapped potentials of HIT-based innovations for improving care in healthcare organizations, only scattered and disconnected evidence was available on topics relating to innovation and quality of HIT in organizational settings prior to this thesis. Specifically, no integrated accounts existed as to how the organizations' capacity to innovate and their information management might be conceptualized (Research Question 1) and how they influence HIT quality (Research Question 2). The results paint a clear picture of how organizational innovation capabilities, i.e., a climate that reflects an openness to HIT-based innovation on various organizational levels, not only drive the adoption of HIT systems but also their quality in terms of workflow support and successful clinical information logistics. Some findings, like the positive influence of the top management team support on measures of HIT quality, were to be expected as prior research found similar effects. Other associations, such as the mediating effect of the professionalism of information management or the country differences in innovation capabilities, were more surprising and are a valuable addition to the body of knowledge.

In a broader sense, the results show that a strong organizational inclination towards innovation does not contradict quality in HIT-related matters. In fact, such inclination appears necessary: HIT-based innovation cannot just be prescribed from outside the organization but must be adopted and translated into HIT workflow support from within. This should encourage healthcare organizations, especially the top management team, to realize the effect their stance towards HIT can have and take agency in developing their HIT systems instead of just reacting to market or legal-financial pressures. However, this is not an individual's endeavor. The organization needs to adopt such attitudes and corresponding behaviors on multiple levels, which, crucially, includes the IT department and professional information management activities. For executives, this implies that they should aim to develop their organization according to the characteristics and activities that are reflected in the respective scale sets, e.g., by selecting for such traits in personnel acquisition or by educating and training the existing staff.

While the findings put responsibility in the hands of the organizations, they also suggest that the legal-financial environment affects HIT quality and innovation capabilities to a certain extent. Policymakers should note this and work on enabling organizations to manage their digital transformation via the mechanisms suggested by the IQ_{HIT} model. This could be pursued through complementary investments aimed at enhancing the organizations' ability to innovate, i.e., investing in the education, development, size, and composition of the organizations' IT and management teams. Correspondingly, digital maturity models used to evaluate such investments need to pick up on the sociotechnical facilitators of HIT quality presented in this thesis.

Outlook

Technological innovation will likely keep pushing the envelope of how healthcare is conducted. Healthcare organizations must be prepared to continuously translate those innovations into effective HIT workflow support and a higher quality of care. Thus, research efforts on what enables them to do so should be expanded on in several ways going forward. First, questions on how organizational innovation capabilities can be built and trained for should increasingly be addressed by both policymakers and managers of healthcare organizations. Secondly, there is a need to move from focusing on how higher degrees of successful digitalization can be achieved to how this can be translated into meaningful benefits for the care provider and the patients. This also implies that the patients need to receive increased attention, not only in terms of incorporating patient-level health outcomes but also with regard to their role in facilitating innovation. While this thesis presupposes that HIT-enabled process innovations are brought about by either macro-level pressures or by the care-providing organization, the increasing integration of patient-centered IT solutions in the form of mobile apps, wearables, and patient portals lead to believe that the patients might soon take on a more active role in facilitating HIT innovations, even in organizational settings.

Addressing these questions and solidifying the findings of this thesis require additional testing, preferably using controlled, longitudinal research designs and backing by qualitative data. This could culminate in the development of an empirically rooted effect model to comprehensively describe the digital transformation in healthcare organizations – from environmental factors to benefit realizations – and this thesis sheds light on what core parts of such an extended model might look like.

Overall, the empirical results inform the theoretical body of knowledge at the intersection between health informatics, implementation research, and management research by highlighting the responsibility and capability of healthcare organizations in managing their digital transformation (see Text box 2 for a summary of the central findings). Simultaneously, the thesis provides various insights for healthcare managers, policymakers, and educators. Most importantly, that it indeed appears like the future belongs to those who seize the opportunities created by innovation.

Text box 2: Central findings and added value of the thesis.

What is new?

- Valid and reliable scale sets for measuring innovation capabilities and the professionalism of information management.
- Insight on the constituents of organizational innovation capabilities and on how they cluster across different organizational levels.
- The IQ_{HIT} model itself in terms of…

  …the various relationships it suggests, particularly with regard to the strong link between innovation capabilities and HIT quality.

  …an empirical model that combines latent phenomena with manifest HIT indicators and, on top of that, factors in the legal-financial environment by including data from different countries.

What findings are surprising or unexpected?

- The strengths of the total effect that the innovation capabilities exhibit across the model – particularly concerning the top management team.
- Country differences not only in HIT quality but also in the innovation capabilities.
- The total mediation effect of the professionalism of information management, i.e., the insight that it is professional information management processes that translate the capacity to innovate into better HIT workflow support. Innovation capabilities on the level of the top management team and the IT department alone are necessary but not sufficient.

What are the scientific implications and further research needs?

The IQ_{HIT} model has opened doors for pursuing new avenues in terms of motivating studies on

- how healthcare organizations develop innovation capabilities.
- how clinicians perceive HIT workflow support and how this relates to other perspectives.
- further validating the model or parts thereof using controlled designs and qualitative data across different legal-financial environments.
- the role of risk-taking, error culture, autonomy, and the patients' involvement in innovation processes.
- model validation (or parts thereof) using controlled designs, multiple perspectives, and qualitative data - preferably across different legal-financial environments.
- how the domains covered in the IQ_{HIT} model relate to realizing medical benefits for the patient, e.g., improved patient safety.

What are the implications for practice?

- Executives and other decision-makers at the organizational level need to be aware of the large impact organizations have in the translational function of establishing higher levels of HIT quality in the care processes by means of the right attitude and climate towards HIT innovation.
- Especially the top management team should be encouraged to take agency in shaping the digital transformation in their organizations.
- Executives and other decision-makers at the organizational level need to be aware of the crucial role of the IT department, both in terms of professional information management practices and in terms of an innovation-friendly climate. This can help in selecting suitable employees.
- Policymakers need to account for organizational issues when designing and evaluating incentive programs to stimulate HIT quality on a broad scale.
- Educators should be aware of the constituents of innovation capabilities and find ways to train for them.

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Appendix

Publication 1

Appendix Table 4: Questionnaire

Items	Feature	Measure	Scale
In which state is your organisation located?			
		states	nominal
Postal code			
		free text	nominal
In which town is your organisation located?			
		free text	nominal
Please indicate the ownership status of your organisation			
		ownership	public
			private
			non-profit
Please indicate the teaching status of your organisation			
		teaching status	university hospital
			general teaching hospital
			no teaching hospital
How many beds does your organisation have?			
		number	metric
Is your organisation affiliated with a system of other hospitals?			
		system affiliation	single hospital
			hospital in a system with … members
Does your hospital have a surgery theatre?			
		existence	yes/no
Please evaluate the innovative power of your organisation with regard to IT			

Items	Feature	Measure	Scale
		perceived innovative power	1 … 10
clinical documentation			
clinical documentation: electronic medical summaries and observation reporting		implementation status	likert scale
clinical documentation: medical minimum dataset		implementation status	likert scale
clinical documentation: nursing documentation		implementation status	likert scale
clinical documentation: medication (order entry)		implementation status	likert scale
clinical documentation: surgery documentation		implementation status	likert scale
clinical documentation: anaesthesia documentation		implementation status	likert scale
clinical documentation: ICU documentation		implementation status	likert scale
order entry and observation reporting			
oder entry and observation reporting: lab values		implementation status	likert scale
oder entry and observation reporting: radiology and nuclear medicine (without images)		implementation status	likert scale
oder entry and observation reporting: radiology and nuclear medicine (images)		implementation status	likert scale
oder entry and observation reporting: electrophysiology (e.g. EEG)		implementation status	likert scale
clinical decision support			
clinical decision support: medical guidelines and clinical pathways		implementation status	likert scale
clinical decision support: clinical reminders		implementation status	likert scale
clinical decision support: alerting		implementation status	likert scale
clinical decision support: medication therapy		implementation status	likert scale
patient safety			

Items	Feature	Measure	Scale
patient safety: electronic identification of lab samples		implementation status	likert scale
patient safety: electronic tracking of medication loop (from ordering to administration)		implementation status	likert scale
patient safety: electronic medication administration documentation		implementation status	likert scale
patient safety: electronic identification of medical supplies and drugs		implementation status	likert scale
patient safety: electronic identification of warehouses and other locations		implementation status	likert scale
patient safety: electronic identification of patients		implementation status	likert scale
patient safety: critical incident reporting system		implementation status	likert scale
supply chain			
supply chain: materials management		implementation status	likert scale
supply chain: pharmacy		implementation status	likert scale
supply chain: meal ordering		implementation status	likert scale
interface function			
interface function: inpatient data management		implementation status	likert scale
interface function: outpatient data management		implementation status	likert scale
interface function: quality management system		implementation status	likert scale
interface function: electronic archive system		implementation status	likert scale
interface function: staff schedule system		implementation status	likert scale
interface function: communication with external providers		implementation status	likert scale
What is the degree of Wi-Fi implementation in your institution?			
		implementation status	likert scale

Items	Feature	Measure	Scale
Which electronic devices do clinicians use for processing patient data? (multiple responses possible)			
	PC	existence	yes / no
	Notebook (Computer on Wheels)	existence	yes / no
	PDA	existence	yes / no
	Bedside Terminal	existence	yes / no
	Tablet-PC	existence	yes / no
	Smartphone	existence	yes / no
	Thin-Client	existence	yes / no
Are clinical routine data in your organisation used for secondary data analysis (e.g. quality management, clinical research, administration)?			
			yes/no
For what type of tasks are these clinical routine data used?			
	Improvement of patient safety	type of tasks (nominal)	yes/no
	Monitoring health outcomes	type of tasks (nominal)	yes/no
	Disease or case management	type of tasks (nominal)	yes/no
	Billing	type of tasks (nominal)	yes/no
	Governance (Data Warehouse)	type of tasks (nominal)	yes/no
	Quality management	type of tasks (nominal)	yes/no
	Clinical research	type of tasks (nominal)	yes/no
	Training and education	type of tasks (nominal)	yes/no
	Identification of evidence based "best practice"	type of tasks (nominal)	yes/no
Please describe the availability of the electronic patient record system in your organisation.			

Items	Feature	Measure	Scale
		implementation status	likert scale
Which parts of the nursing process are supported by the nursing software used in your organisation?			
	Documentation of nursing measures	existence	yes / no
	Documentation of problems	existence	yes / no
	Scores	existence	yes / no
	Nursing assessment	existence	yes / no
	Documentation of nursing goals	existence	yes / no
	Documentation of ressources	existence	yes / no
	Documentation of goal evaluation	existence	yes / no
Which special documentation features does the software have?			
	PKMS	existence	yes / no
	DRG-relevant nursing diagnosis	existence	yes / no
	Wound documentation	existence	yes / no
	MRSA documentation	existence	yes / no
	Hygiene documentation	existence	yes / no
Nursing problems are documented using ….			
	Catalogue based on ICNP	existence	use (currently or planned)
	Free text	existence	use (currently or planned)
	NANDA-I catalogue in German	existence	use (currently or planned)
	Proprietary catalogue	existence	use (currently or planned)
	EPA-AC	existence	use (currently or planned)
	ENP	existence	use (currently or planned)

Items	Feature	Measure	Scale
	apenio	existence	use (currently or planned)
	ICF	existence	use (currently or planned)
	Other	existence	use (currently or planned)
Nursing measures are documented using ….			
	Catalogue based on ICNP	existence	use (currently or planned)
	Free text	existence	use (currently or planned)
	Proprietory catalogue	existence	use (currently or planned)
	LEP 2.x	existence	use (currently or planned)
	LEP 3.x	existence	use (currently or planned)
	ENP	existence	use (currently or planned)
	apenio	existence	use (currently or planned)
	NIC	existence	use (currently or planned)
	Other	existence	use (currently or planned)
Which patient data are available on PC workstations for ward rounds? (multiple responses possible)			
	patient demographics	existence	yes / no
	results (text)	existence	yes / no
	results (images)	existence	yes / no
	results (electrophysiology)	existence	yes / no
	kardex with medication and vital signs	existence	yes / no
	warnings	existence	yes / no
	orders	existence	yes / no
Which patient data are available on mobile devices (e.g. over smartphone)? (multiple responses possible)			

Items	Feature	Measure	Scale
	patient demographics	existence	yes / no
	results (text)	existence	yes / no
	results (images)	existence	yes / no
	results (electrophysiology)	existence	yes / no
	kardex with medication and vital signs	existence	yes / no
	warnings	existence	yes / no
	orders	existence	yes / no
How many clinical units have an in-patient access to patient data?			
		relative number of units	percent
How many clinical units in your institution do have mobile access to the patient data?			
		relative number of units	percent
Please evaluate the overall use of electronic patient data during ward rounds			
	The completness of data is …	quality	good / acceptable / bad
	The up-to-dateness of data is …	quality	good / acceptable / bad
	The time it takes to compile data is …	quality	good / acceptable / bad
Is the surgery date scheduled electronically in your institution?			
		existence	yes / no
Which electronic data is accessable for the anesthetist and surgeon before surgery? (multiple responses possible)			
	patient demographics	existence	yes / no
	results (text)	existence	yes / no
	results (images)	existence	yes / no
	results (electrophysiology)	existence	yes / no
	kardex with medication and vital signs	existence	yes / no

Items	Feature	Measure	Scale
	warnings	existence	yes / no
	orders	existence	yes / no
Please evaluate the overall use of electronic patient data during pre-surgery			
	The completness of data is …	quality	good / acceptable / bad
	The up-to-dateness of data is …	quality	good / acceptable / bad
	The time it takes to compile data is …	quality	good / acceptable / bad
In which format are patient data transmitted to the normal ward and the intensive care unit?			
normal ward	electronic format for all data (structured data)	type of format	
	electronic format for specific data (structured data)		
	via an electronic document management system (e.g. PDF)		
	paper based		
intensive care unit	electronic format for all data (structured data)	type of format	
	electronic format for specific data (structured data)		
	via an electronic document management system (e.g. PDF)		
	paper based		
Which electronic data from the surgery are available on the normal ward? (multiple responses possible)			
	patient demographics	existence	yes / no
	results (text)	existence	yes / no
	results (images)	existence	yes / no
	results (electrophysiology)	existence	yes / no
	kardex with medication and vital signs	existence	yes / no

Items	Feature	Measure	Scale
	warnings	existence	yes / no
	orders	existence	yes / no
Which electronic data from the surgery are available on the intensive care unit? (multiple responses possible)			
	patient demographics	existence	yes / no
	results (text)	existence	yes / no
	results (images)	existence	yes / no
	results (electrophysiology)	existence	yes / no
	kardex with medication and vital signs	existence	yes / no
	warnings	existence	yes / no
	orders	existence	yes / no
Please evaluate the overall use of electronic patient data during post-surgery			
	The completness of data is …	quality	good / acceptable / bad
	The up-to-dateness of data is …	quality	good / acceptable / bad
	The time it takes to compile data is …	quality	good / acceptable / bad
Are there electronic reminder functions for physicians and nurses concerning pending actions (e.g. orders) for patients before discharge?			
		existence	yes / no
How many clinical units have access to an electronic system that supports medical guidelines or clinical pathways?			
		relative number of units	percent
Which data is automatically provided in electronic form for the medical summary? (multiple responses possible)			
	patient demographics	existence	yes / no
	results (text)	existence	yes / no

Items	Feature	Measure	Scale
	results (images)	existence	yes / no
	results (electrophysiology)	existence	yes / no
	kardex with medication and vital signs	existence	yes / no
	surgery data	existence	yes / no
Is the medical summary made available electronically to the general practitioners?			
	yes, via a portal	existence	yes / no
	yes, via eMail	existence	yes / no
	yes, via other IT systems	existence	yes / no
	not	existence	yes / no
Please evaluate the overall use of electronic patient data during discharge			
	The completness of data is …	quality	good / acceptable / bad
	The up-to-dateness of data is …	quality	good / acceptable / bad
	The time it takes to compile data is …	quality	good / acceptable / bad
Are nursing reports created electronically?			
			yes / no
Which parts of the nursing process can be incorporated into the electronic nursing report?			
	Documentation of nursing measures	existence	yes / no
	Documentation of problems	existence	yes / no
	Scores	existence	yes / no
	Nursing assessment	existence	yes / no
	Documentation of nursing goals	existence	yes / no
	Documentation of ressources	existence	yes / no
	Documentation of goal evaluation	existence	yes / no

Items	Feature	Measure	Scale
Which special documentation features can be incorporated into the electronic nursing report?			
	PKMS	existence	yes / no
	DRG-relevant nursing diagnosis	existence	yes / no
	Wound documentation	existence	yes / no
	MRSA documentation	existence	yes / no
	Hygiene documentation	existence	yes / no
Please evaluate the overall use of electronic patient data for the electronic nursing report			
	The completness of data is …	quality	good / acceptable / bad
	The up-to-dateness of data is …	quality	good / acceptable / bad
	The time it takes to compile data is …	quality	good / acceptable / bad
How satisfied are you with the software used to support the clinical workflows			
	Ward round	satisfaction	likert scale
	Pre-surgery	satisfaction	likert scale
	Post-surgery	satisfaction	likert scale
	Discharge	satisfaction	likert scale
How satisfied are you with the cooperation with the IT department regarding the support of clinical workflows			
		satisfaction	likert scale
Is your organisation a reference customer of an IT vendor?			
		existence	yes / no
Is there a central IT department in your organisation?			
		existence	yes / no
Who takes the project lead when implementing IT projects in the clinical practice?			

Items	Feature	Measure	Scale
		profession	Employee of the IT department
			Physicians / nurses (Key-User)
			Employee of the IT department together with a physician / nurse
Is there a physician or nurse responsible for IT matters in your organisation?			
	A physician is responsible for IT matters	responsibility	yes / no
	A nurse is responsible for IT matters	responsibility	yes / no
What role do physicians / nurses (Key-User) play in your organisation with regard to IT matters?			
	They contribute to the IT strategy development		yes / no
	They contribute to evaluating and selecting new IT systems		yes / no
	They act as project manager at the clinical end for IT implementation and training		yes / no
	They contribute to the development and conduct of clinical training		yes / no
	They support clinical IT functions on behalf of the IT department		yes / no
	They work on innovative means to integrate IT into clinical practice		yes / no

Appendix Table 5: Comparison of samples and populations

Indicator	Population	Sample	Statistic	p-value
Germany				
Teaching hospitals	43.23% [$n = 1765$]	45.91% [$n = 464$]	0.963	0.326
For-profit hospitals	29.19% [$n = 1737$]	24.94% [$n = 441$]	2.916	0.088

Indicator	Population	Sample	Statistic	p-value
Hospital size (Bed Count)	290.84 [n = 1765]	299.52 [n = 464]	-0.538	0.591
Austria				
For-profit hospitals	44.16% [n = 274]	42.65% [n = 68]	0.007	0.929
Hospital size (bed count)	232.00 [n = 274]	298.04 [n = 70]	–1.757	0.082

We used Pearson's Chi-Square tests as null hypothesis significance tests for the proportion of teaching hospitals and for-profit hospitals. To compare the hospital size, measured by bed count, we used the Welch Two Sample t-test.

Appendix Table 6: Multiple linear regression model on "IT function" sub-score

Independent variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
(Intercept)	31.750 (1.441)***	28.948 (1.437)***	28.949 (1.433)***	28.713 (1.525)***	28.725 (1.702)***	29.081 (1.860)***	30.578 (1.981)***
Innovative power	3.532 (0.226)***	3.509 (0.221)***	3.447 (0.223)***	3.523 (0.235)***	3.523 (0.235)***	3.437 (0.243)***	3.314 (0.256)***
Hospital size		0.010 (0.002)***	0.010 (0.002)***	0.009 (0.002)***	0.009 (0.002)***	0.010 (0.002)***	0.009 (0.002)***
Country ("Austria" as reference)			2.510 (1.392)	3.266 (1.470)*	3.265 (1.473)*	3.826 (1.524)*	4.584 (1.850)*
Hospital system affiliation ("hospital in a system" as reference)				1.687 (0.690)*	1.688 (0.694)*	1.576 (0.708)*	1.384 (0.758)
Availability of surgery ("surgery available" as reference)					–0.019 (1.124)	–0.070 (1.159)	–0.595 (1.290)
Ownership ("for-profit hospital" as reference)						–0.072 (1.231)	0.713 (1.425)
Teaching status ("teaching hospitals" as reference)							–0.037 (1.202)
R^2	0.344	0.417	0.421	0.433	0.433	0.425	0.415
Adj. R^2	0.343	0.414	0.417	0.428	0.426	0.416	0.403
Num. obs.	469	450	450	411	411	396	351
RMSE	10.432	9.941	9.916	9.852	9.865	9.867	9.874

Results of the Forward Selection Models. In each iteration, one variable is added that contributes most to the explained variance. Within the brackets we show the standard error of the regression coefficients.

Appendix Table 7: Adjusted odds ratios for all IT functions

IT-Function	Germany	Austria	Adjusted odds ratios	p-value
Identification of samples	63.68% [*n* = 424]	40.62% [*n* = 64]	0.385 [0.208–0.702]**	0.002
Lab values	82.85% [*n* = 449]	69.12% [*n* = 68]	0.604 [0.308–1.225]	0.150
Quality management system	50.48% [*n* = 420]	43.55% [*n* = 62]	0.678 [0.373–1.214]	0.194
Electrophysiology (e.g. EEG)	47.66% [*n* = 449]	38.24% [*n* = 68]	0.697 [0.386–1.235]	0.221
Surgery documentation	88.15% [*n* = 329]	73.91% [*n* = 46]	0.720 [0.300–1.937]	0.484
Anaesthesia documentation	49.03% [*n* = 463]	37.14% [*n* = 70]	0.798 [0.443–1.423]	0.447
Staff scheduling system	85.44% [*n* = 419]	82.26% [*n* = 62]	0.853 [0.400–1.964]	0.692
Outpatient accounting	58.81% [*n* = 420]	51.61% [*n* = 62]	0.876 [0.478–1.625]	0.671
Medical minimum dataset	68.97% [*n* = 464]	67.14% [*n* = 70]	1.054 [0.586–1.955]	0.864
Radiology and nuclear medicine (with images)	61.25% [*n* = 449]	58.82% [*n* = 68]	1.153 [0.615–2.200]	0.659
Other examination reports (e.g. sonography)	46.88% [*n* = 448]	47.06% [*n* = 68]	1.155 [0.642–2.076]	0.628
Inpatient accounting	75.48% [*n* = 420]	77.42% [*n* = 62]	1.188 [0.589–2.574]	0.645
Alerting	38.26% [*n* = 426]	36.92% [*n* = 65]	1.210 [0.666–2.173]	0.527
Critical incident reporting system	44.21% [*n* = 423]	46.15% [*n* = 65]	1.280 [0.700–2.347]	0.422
Radiology and nuclear medicine (without images)	53.90% [*n* = 449]	54.41% [*n* = 68]	1.286 [0.709–2.364]	0.411
Pharmacy	62.38% [*n* = 420]	69.35% [*n* = 62]	1.329 [0.713–2.568]	0.381
Medical guidelines and clinical pathways	29.34% [*n* = 426]	38.46% [*n* = 65]	1.412 [0.772–2.541]	0.254
Materials management	57.38% [*n* = 420]	64.52% [*n* = 62]	1.489 [0.793–2.874]	0.223
Other councils	33.94% [*n* = 436]	39.34% [*n* = 61]	1.511 [0.784–2.877]	0.211
Clinical reminders	19.95% [*n* = 426]	27.69% [*n* = 65]	1.571 [0.807–2.967]	0.172

IT-Function	Germany	Austria	Adjusted odds ratios	p-value
Meal ordering	62.62% [n = 420]	66.13% [n = 62]	1.622 [0.791–3.448]	0.196
Communication with external providers	7.62% [n = 420]	12.90% [n = 62]	1.766 [0.700–4.053]	0.199
Medication (order entry)	23.92% [n = 464]	37.14% [n = 70]	2.156 [1.214–3.797]*	0.008
Electronic archive system	34.76% [n = 420]	53.23% [n = 62]	2.268 [1.247–4.165]*	0.008
Medication administration documentation	11.82% [n = 423]	24.62% [n = 65]	2.484 [1.223–4.874]*	0.009
ICU documentation	18.10% [n = 464]	30.00% [n = 70]	2.489 [1.291–4.722]*	0.006
Electronic nursing documentation	31.25% [n = 464]	67.14% [n = 70]	5.981 [3.276–11.372]***	0.000

Implementation Rates per Country and corresponding Odds Ratios (and 95% CI) derived from a logistic regression analysis where country served as criterion ("Austria" as reference).

Publication 4

Appendix 1: Extract of the questionnaire from the second quantitative survey

Question	Response options
Are the following information management activities or procedures performed in your hospital? I. Strategic tasks & processes	
• Preparation and further development of an information management strategy	Regularly / Irregularly / Not at all
• Strategic controlling in terms of IT project management including project portfolios	Regularly / Irregularly / Not at all
• Long-term finance and investment planning	Regularly / Irregularly / Not at all
• Strategic risk management (e.g. maintenance of emergency plans)	Regularly / Irregularly / Not at all
• Evaluation of IT efficiency benefits	Regularly / Irregularly / Not at all
Are the following information management activities or procedures performed in your hospital? II. Procurement & implementation	
• System analysis and evaluation (e.g. process modelling, evaluation of the current state)	Regularly / Irregularly / Not at all
• System specification (e.g. requirements definition, specifications, migration plan)	Regularly / Irregularly / Not at all
• System selection (e.g. market analysis, tendering, bid comparison)	Regularly / Irregularly / Not at all
• System implementation (e.g. implementation strategy and adaptation)	Regularly / Irregularly / Not at all
• Further cooperation with manufacturers (for product development / enhancement)	Regularly / Irregularly / Not at all
Are the following information management activities or procedures performed in your hospital? III. Operational tasks & processes	
• Application support and maintenance	Regularly / Irregularly / Not at all
• Management and monitoring of the technical performance (infrastructure and networks)	Regularly / Irregularly / Not at all
• Training of clinical end users	Regularly / Irregularly / Not at all
• Evaluation of user satisfaction	Regularly / Irregularly / Not at all
• Running of the help desk and / or service desk	Regularly / Irregularly / Not at all
Do defined IT management processes exist in your institution in terms of IT governance (e.g. based on COBIT or ITIL)?	Yes / No
Does your institution have a strategic IT plan and to what extent is it integrated into the strategic hospital plan?	We have no strategic IT plan / We are developing a strategic IT plan / There is an IT plan, but it is not aligned with the hospital strategy / The IT plan is aligned with or an integral part of the hospital strategy

Abbreviations: COBIT, control objectives for information and related technology; IT, information technology; ITIL, IT infrastructure library.

Appendix 2: Individual medians of professionalism of the information management items

Item	Dimension	Primary phase	Median	IQR
Application support and maintenance	Operational	Implementation	Regularly	Regularly
Management and monitoring of the technical performance [*n* = 223]	Operational	Implementation	Regularly	Regularly
Running of the help desk and/or service desk	Operational	Implementation	Regularly	Regularly
Training of clinical end users	Operational	Implementation	Regularly	Regularly to irregularly
System implementation	Tactical	Implementation	Regularly	Regularly to irregularly
Long-term finance and investment planning	Strategic	Planning	Regularly	Regularly to irregularly

System selection	Tactical	Implementation	Irregularly	Regularly to irregularly
Strategic risk management	Strategic	Planning	Irregularly	Regularly to irregularly
Strategic controlling in terms of IT project management including project portfolios	Strategic	Planning	Irregularly	Regularly to irregularly
System specification	Tactical	Implementation	Irregularly	Regularly to irregularly
Preparation and further development of an information management strategy	Strategic	Planning	Irregularly	Regularly to irregularly
Further cooperation with manufacturers	Tactical	Implementation	Irregularly	Irregularly
System analysis and evaluation	Tactical	Evaluation	Irregularly	Irregularly
Evaluation of user satisfaction	Strategic	Evaluation	Irregularly	Irregularly to not at all
Evaluation of IT efficiency benefits	Strategic	Evaluation	Not at all	Irregularly to not at all

Abbreviations: IQR, interquartile range; IT, information technology.

Publication 5

Appendix Table 1: Measurement models and underlying items (questionnaire part A)

	Measurement Model	Value, mean (SD)[a]	Indicator			
			Question	Code	Label/Sub-question	Scale/Categories
Professionalism of Information Management (PIM)[b]	Strategic Information Management (PIM_1)	54.2 (24.6)	Are the following IT management activities or procedures performed in your hospital?	PIM_1_S1	Preparation and further development of an information management strategy	Categorical (not at all, irregularly, regularly)
				PIM_1_S2	Strategic controlling in terms of IT project management including project portfolios	
				PIM_1_S3	Long-term finance and investment planning	
				PIM_1_S4	Strategic risk management (e.g. maintenance of emergency plans)	
				PIM_1_S5	Evaluation of IT efficiency benefits	
				PIM_1_S6	Evaluation of user satisfaction	
	Tactical Information Management (PIM_2)	60.7 (17.4)	Are the following IT management activities or procedures performed in your hospital?	PIM_2_T1	Workflow analysis and evaluation (e.g. process modeling, evaluation of the current state)	Categorical (not at all, irregularly, regularly)
				PIM_2_T2	System specification (e.g. requirements definition, specifications, migration plan)	
				PIM_2_T3	System selection (e.g. market analysis, tendering, bid comparison)	
				PIM_2_T4	System implementation (e.g. implementation strategy and adaptation)	
				PIM_2_T5	Further cooperation with manufacturers (for product development/enhancement)	
	Operational Information Management (PIM_3)	85.7 (20.1)	Are the following IT management activities or procedures performed in your hospital?	PIM_3_O1	Application management and maintenance	Categorical (not at all, irregularly, regularly)
				PIM_3_O2	Management and monitoring of the technical performance (infrastructure and networks)	
				PIM_3_O3	Training of clinical end users	
				PIM_3_O4	Continuous operation of the help desk/service desk	
Innovation Capability: Top Management Team Support (IC TMT)		62.6 (19.9)	Please indicate your (dis-) agreement with the following statements.	IC_TMT_1	"Our hospital has a well-defined future vision that is shared by the IT department."	Five-point Likert scale (strongly disagree-strongly agree).
				IC_TMT_2	"Our executive board regularly seeks the exchange with the CIO."	
				IC_TMT_3	"I have often been given positive feedback from the executive board for contributing innovative ideas."	
				IC_TMT_4	"Our executive board explicitly calls for proposals of innovative eHealth solutions."	
				IC_TMT_5	"Our executive board actively promotes the initiation of new IT projects."	
				IC_TMT_6	"Our executive board regularly perceives IT as a mere expense factor." (reverse coded)	

Innovation Capability of the IT Department (IC ITD)	71.1 (15.5)	Please indicate your (dis-) agreement with the following statements.	IC_ITD_1	"In the IT department, we regularly discuss new IT solutions with representatives of the specialist departments (clinical users)."	Five-point Likert scale (strongly disagree-strongly agree).
			IC_ITD_2	"In our team, creative ideas and suggestions for new IT applications are carefully listened to and discussed."	
			IC_ITD_3	"Everyone in my team needs certain degrees of freedom in order to come up with the best possible solutions."	
			IC_ITD_4	"Employee creativity is a major driving force in our IT department."	
			IC_ITD_5	"Our IT team has often shown a strong sense of cohesion."	
Organization-Wide Innovation Capability (IC OW)	59.4 (17.7)	Please indicate your (dis-) agreement with the following statements.	IC_OW_1	"Our entire hospital shows great agility and flexibility when it comes to implementing and using new IT solutions."	Five-point Likert scale (strongly disagree-strongly agree).
			IC_OW_2	"In our hospital, new IT projects are openly communicated and discussed between all participants."	
			IC_OW_3	"Our hospital is far too inflexible at all levels of hierarchy to use IT solutions in a meaningful way." (reverse coded)	
			IC_OW_4	"The responsiveness of our IT landscape to new requirements is excellent."	
			IC_OW_5	"Our users and employees often have a fundamental aversion to IT." (reverse coded)	
Perceived HIT Workflow Support (PHITS)	69.8 (15.7)	How well do the various IT-systems support the following workflows overall?	PHITS _1	Admission	Grades (very good, good, satisfactory, sufficient, poor)
			PHITS _2	Ward rounds	
			PHITS _3	Pre-surgery	
			PHITS _4	Post-surgery	
			PHITS _5	Discharge	
Clinical IT-Agents (CITA)	31.5 (30.9)	Are there any physicians or nurses in your hospital who are officially responsible for IT matters?	CITA_1	At least one physician is officially responsible for IT matters.	Binary (Yes/No)
			CITA_2	At least one nurse is officially responsible for IT matters.	
Overall Goodness of Information Provision[c]	68.4 (19.3)	Please indicate your (dis-) agreement with the following statement.	OGIP	Our hospital always provides the right information, at the right time, at the right place, for the right persons, and in the right quality to support clinical processes.	Five-point Likert scale (strongly disagree-strongly agree).
Structural Characteristics (SC)[d]		How many beds does your hospital have?	SC_1		Metric (bed count)

		What is the teaching status of your hospital?	SC_2	Categorical (nonteaching, minor teaching, major teaching)
Country[cde]			COU	Categorical (Austria, Germany, Switzerland)
Workflow Composite Score (WCS)[cf]	55.9 (13.7)		WCS	Metric (ranges from 0 to 100 points)

[a] Sum based composite scores for each measurement model, transformed to range from 0-100.

[b] This higher order construct PIM has a mean (SD) of 64.8 (19.2).

[c] Single item scale.

[d] See Table 3 for descriptive information.

[e] No question associated with this variable, as it was not part of the questionnaire, but was added subsequently.

[f] Calculated based on a fixed structure of 146 underlying questionnaire items (questionnaire part B, see Appendix table 2)

Appendix Table 2: Workflow Composite Score (WCS): Structure and underlying items (questionnaire part B)

Each item of the questionnaire part B is assigned to one descriptor (“Functions”, “Data & Information”, “Distribution” or “Integration & Interoperability”) and to one or more clinical processes (“Admission”, “Ward Rounds”, “Pre-Surgery”, “Post-Surgery” and “Discharge”) – For example, CPOE functions are deemed relevant in all clinical processes while a function for writing discharge letter is only relevant for the discharge process. Based on this assignment, the WCS is calculated using a hierarchical structure: First, a score for each descriptor in each of the five processes (i.e. a total of 20 descriptor scores) is calculated by summing up the products of the standardized raw data of each item of that descriptor with their individual weight. Secondly, all descriptor scores of a given clinical process are summed up to form the composite score of that process. The four descriptors are equally weighted within each process scores (i.e. each descriptor makes up a maximum of 25% of the clinical process score). Lastly, the WCS is calculated as the mean of all five clinical process scores. For further information please refer to Liebe et al. 2015 [17], Esdar et al. 2017 [43] and Hübner et al. 2018 [65].

Item	Descriptor	Weights				
		Admission	Ward Rounds	Pre-Surgery	Post-Surgery	Discharge
Documentation functions: Does your hospital provide an IT function for writing discharge summaries (doctor's letters)? [a]	Functions					1.83%
Documentation functions: Does your hospital provide an IT function for writing physician notes (medical reports)? [a]		.48%		.41%	.47%	.46%
Documentation functions: Does your hospital provide an IT function for basic medical documentation (patient master data, diagnoses and therapies etc.)? [a]		.48%	.62%	.41%	.47%	.46%
Documentation functions: Does your hospital provide an IT function for doing nursing assessments? [a]		.48%	.62%	.41%	.47%	.46%
Documentation functions: Does your hospital provide an IT function for operation notes in surgery (surgery documentation)? [a]				.80%	.94%	
Documentation functions: Does your hospital provide an IT function for anesthesia documentation? [a]				1.33%	.94%	
Documentation functions: Does your hospital provide an IT function for ICU documentation ("PDMS")? [a]		.48%	.62%	.80%	.47%	.46%
Documentation functions: Does your hospital provide an IT function for documentation of other therapeutic specialists (e.g. physical therapists)? [a]		.48%	.62%			.46%

Documentation functions: Does your hospital provide an IT function for wound assessment and documentation? [a]	.48%	.62%	.41%	.47%	.46%
Documentation functions: Does your hospital provide an IT function for hygiene documentation? [a]	.48%	.62%	.41%	.47%	.46%
CPOE: Does your hospital provide an IT function for order entry and results viewing of laboratory data? [a]	.53%	1.63%	.46%	.71%	.68%
CPOE: Does your hospital provide an IT function for order entry and results viewing of radiology reports (e.g. realized in conjunction with a RIS)? [a]	.53%	1.63%	.46%	.71%	.68%
CPOE: Does your hospital provide an IT function for order entry and results viewing of radiology images (e.g. realized in conjunction with a PACS)? [a]	.53%	1.63%	.46%	.71%	.68%
CPOE: Does your hospital provide an IT function for order entry and results viewing of electrophysiological examinations (e.g. ECG, EEG)? [a]	.53%	1.63%	.46%	.71%	.68%
CPOE: Does your hospital provide an IT function for order entry and results viewing of sonographic and endoscopic examinations? [a]	.53%	1.63%	.46%	.71%	.68%
CPOE: Does your hospital provide an IT function for order entry and results viewing of medical councils? [a]	.53%	1.63%	.46%	.71%	.68%
CDSS: Does your hospital IT system integrate medical guidelines and clinical pathways? [a]	.53%	.62%	.46%	.61%	.52%
CDSS: Does your hospital IT system integrate clinical reminders (e.g. listing of patients for whom treatment measures are still pending)? [a]	.53%	.62%	.46%	.61%	1.05%
CDSS: Does your hospital IT system integrate alarms (e.g. lab values outside the normal range)? [a]	.53%	.62%	.46%	1.22%	.52%
CDSS: Does your hospital provide an IT function for supporting the pharmaceutical therapy (e.g. drug interaction checker)? [a]	.53%	.62%	.46%	.61%	
CDSS: Does your hospital provide an IT function for accessing clinical databases / medical knowledge at the point of care (e.g. UpToDate or similar products)? [a]	.53%	.62%	.46%	.61%	.52%
CDSS: Does your hospital provide other clinical decision support systems for diagnostics, therapy or nursing that are not related to the medication? [a]	.53%	.62%	.46%	.61%	.52%
Patient Safety Systems: Does your hospital provide an IT function for identifying laboratory samples? [a]	.53%	.62%	.32%	.63%	.62%
Patient Safety Systems: Does your hospital provide an IT function for tracking pharmaceuticals (from the pharmacy until administration)? [a]		.62%	.32%	.63%	
Patient Safety Systems: Does your hospital provide an IT function for order entry of pharmaceuticals (medication)? [a]	.53%	.62%	.32%	.63%	
Patient Safety Systems: Does your hospital provide an IT function for medication administration (eMAR)? [a]	.53%		.32%	.63%	
Patient Safety Systems: Does your hospital provide an IT function for identifying patients? [a]	.53%	.62%	.64%	.63%	.62%
Patient Safety Systems: Does your hospital have a critical incident reporting system (CIRS)? [a]	.53%	.62%	.32%	.63%	.62%
Patient Safety Systems: Does your hospital provide an IT function for checklists (e.g. in the OR)? [a]	.53%	.62%	.64%	.63%	.62%
Supply systems: Does your hospital provide an IT function for material logistics using standards (e.g. GTIN, EAN, PZN)? [b]	.42%	.50%	.39%	.58%	
Supply systems: Does your hospital provide an IT function for material logistics without standards? [b]	.42%	.50%	.39%	.58%	
Supply systems: Does your hospital provide an IT system for the pharmacy? [b]	.42%	.50%	.39%	.58%	
Supply systems: Does your hospital provide an IT function for food orders? [b]	.42%	.50%	.39%	.58%	
Cross-sectional functions: Does your hospital provide an IT function for the administration of inpatients (admission /transfer / discharge)? [b]	.42%	.67%	.39%	.58%	.67%
Cross-sectional functions: Does your hospital provide an IT function for the administration of outpatients? [b]	.42%		.39%	.58%	
Cross-sectional functions: Does your hospital provide an IT function for quality management? [b]	.42%	.67%	.39%	.58%	.67%

Cross-sectional functions: Does your hospital IT system integrate an electronic archive? [b]		.42%	.67%	.39%	.58%	.67%
Telemedicine & -monitoring: Does your hospital provide an IT function for telemedicine services (e.g. for second opinions or case conferences) [b]		.42%		.48%	.62%	
Telemedicine & -monitoring: Does your hospital provide an IT function for telemonitoring (e.g. for patients with a pacemaker) [b]		.42%			.62%	.72%
Admission: Does your hospital provide an IT function for triage in the emergency department? [b]		1.58%				
Admission: Does your hospital provide an IT function for supporting the anamnesis and patient information? [a]		1.58%		.69%		
Admission: Does your hospital provide an IT function for inpatient allocation management? [b]		1.58%		.69%	.61%	.72%
Operating theater: Does your hospital provide an IT function for surgery planning: Scheduling? [c]		.49%		1.83%		
Operating theater: Does your hospital provide an IT function for surgery planning: Room allocation? [c]		.49%		1.83%		
Operating theater: Does your hospital provide an IT function for surgery planning: Resource planning (materials and staff)? [c]		.49%		1.83%		
Discharge: Does your hospital provide an IT function for creating and updating the patients' medication plan? [a]						1.71%
Discharge: Does your hospital provide an IT function for digital dictation? [a]						1.71%
Discharge: Does your hospital provide an IT function for exchanging data with outside practitioners (e.g. portal solutions or shared health records)? [a]		1.04%				1.71%
Discharge: Does your hospital provide an IT function for creating nursing summaries for subsequent care stages? [a]						1.71%
Are patients able to book appointments online? [c]		.66%		.48%		
Can data obtained in the operating theatre be used to automatically create evaluations and reports for improving procedures? [c]				.69%	.89%	
Which data from previous care stages are electronically available to clinical users? Patient demographics [c]		3.13%				
Which data from previous care stages are electronically available to clinical users? Case data ((coded) diagnoses and therapies) [c]		3.13%				
Which data from previous care stages are electronically available to clinical users? Observation reports (text) [c]		3.13%				
Which data from previous care stages are electronically available to clinical users? Observation reports (images) [c]		3.13%				
Which data from previous care stages are electronically available to clinical users? Electrophysiological reports [c]		3.13%				
Which data from previous care stages are electronically available to clinical users? Discharge summary (including medication & vital signs) [c]	Data & Information	3.13%				
Which data from previous care stages are electronically available to clinical users? Surgery reports [c]		3.13%				
Which data from previous care stages are electronically available to clinical users? Other data [c]		3.13%				
Which data are electronically available for ward rounds (not mobile, e. g. stationary computers, bedside terminals etc.)? Patient demographics [c]			.36%			
Which data are electronically available for ward rounds (not mobile, e. g. stationary computers, bedside terminals etc.)? Case data ((coded) diagnoses and therapies) [c]			.36%			
Which data are electronically available for ward rounds (not mobile, e. g. stationary computers, bedside terminals etc.)? Order entries [c]			.36%			
Which data are electronically available for ward rounds (not mobile, e. g. stationary computers, bedside terminals etc.)? Observation reports (text) [c]			.36%			

Which data are electronically available for ward rounds (not mobile, e. g. stationary computers, bedside terminals etc.)? Observation reports (images) [c]	.36%
Which data are electronically available for ward rounds (not mobile, e. g. stationary computers, bedside terminals etc.)? Electrophysiological reports [c]	.36%
Which data are electronically available for ward rounds (not mobile, e. g. stationary computers, bedside terminals etc.)? Vital signs and medication [c]	.36%
Which data are electronically available for ward rounds (not mobile, e. g. stationary computers, bedside terminals etc.)? Warnings [c]	.36%
Which data are electronically available for ward rounds (not mobile, e. g. stationary computers, bedside terminals etc.)? Checklists [c]	.36%
Which data are electronically available for ward rounds (not mobile, e. g. stationary computers, bedside terminals etc.)? Other data [c]	.36%
Which data are electronically available for ward rounds (mobile, e. g. smartphones, tablets, computer on wheels etc.)? Patient demographics [c]	1.43%
Which data are electronically available for ward rounds (mobile, e. g. smartphones, tablets, computer on wheels etc.)? Case data ((coded) diagnoses and therapies) [c]	1.43%
Which data are electronically available for ward rounds (mobile, e. g. smartphones, tablets, computer on wheels etc.)? Order entries [c]	1.43%
Which data are electronically available for ward rounds (mobile, e. g. smartphones, tablets, computer on wheels etc.)? Observation reports (text) [c]	1.43%
Which data are electronically available for ward rounds (mobile, e. g. smartphones, tablets, computer on wheels etc.)? Observation reports (images) [c]	1.43%
Which data are electronically available for ward rounds (mobile, e. g. smartphones, tablets, computer on wheels etc.)? Electrophysiological reports [c]	1.43%
Which data are electronically available for ward rounds (mobile, e. g. smartphones, tablets, computer on wheels etc.)? Vital signs and medication [c]	1.43%
Which data are electronically available for ward rounds (mobile, e. g. smartphones, tablets, computer on wheels etc.)? Warnings [c]	1.43%
Which data are electronically available for ward rounds (mobile, e. g. smartphones, tablets, computer on wheels etc.)? Checklists [c]	1.43%
Which data are electronically available for ward rounds (mobile, e. g. smartphones, tablets, computer on wheels etc.)? Other data [c]	1.43%
Which data are electronically available for anesthetists, surgeons or surgical nurses before the surgery? Patient demographics [c]	2.50%
Which data are electronically available for anesthetists, surgeons or surgical nurses before the surgery? Case data ((coded) diagnoses and therapies) [c]	2.50%
Which data are electronically available for anesthetists, surgeons or surgical nurses before the surgery? Order entries [c]	2.50%
Which data are electronically available for anesthetists, surgeons or surgical nurses before the surgery? Observation reports (text) [c]	2.50%
Which data are electronically available for anesthetists, surgeons or surgical nurses before the surgery? Observation reports (images) [c]	2.50%
Which data are electronically available for anesthetists, surgeons or surgical nurses before the surgery? Electrophysiological reports [c]	2.50%
Which data are electronically available for anesthetists, surgeons or surgical nurses before the surgery? Vital signs and medication [c]	2.50%

Which data are electronically available for anesthetists, surgeons or surgical nurses before the surgery? Warnings [c]		2.50%		
Which data are electronically available for anesthetists, surgeons or surgical nurses before the surgery? Checklists [c]		2.50%		
Which data are electronically available for anesthetists, surgeons or surgical nurses before the surgery? Other data [c]		2.50%		
Which data are electronically available on regular wards after the surgery? Patient demographics [c]	.36%		1.25%	.42%
Which data are electronically available on regular wards after the surgery? Case data ((coded) diagnoses and therapies) [c]	.36%		1.25%	.42%
Which data are electronically available on regular wards after the surgery? Order entries [c]	.36%		1.25%	.42%
Which data are electronically available on regular wards after the surgery? Observation reports (text) [c]	.36%		1.25%	.42%
Which data are electronically available on regular wards after the surgery? Observation reports (images) [c]	.36%		1.25%	.42%
Which data are electronically available on regular wards after the surgery? Electrophysiological reports [c]	.36%		1.25%	.42%
Which data are electronically available on regular wards after the surgery? Vital signs and medication [c]	.36%		1.25%	.42%
Which data are electronically available on regular wards after the surgery? Warnings [c]	.36%		1.25%	.42%
Which data are electronically available on regular wards after the surgery? Checklists [c]	.36%		1.25%	.42%
Which data are electronically available on regular wards after the surgery? Other data [c]	.36%		1.25%	.42%
Which data are electronically available on ICU's after the surgery? Patient demographics [c]	.36%		1.25%	.42%
Which data are electronically available on ICU's after the surgery? Case data ((coded) diagnoses and therapies) [c]	.36%		1.25%	.42%
Which data are electronically available on ICU's after the surgery? Order entries [c]	.36%		1.25%	.42%
Which data are electronically available on ICU's after the surgery? Observation reports (text) [c]	.36%		1.25%	.42%
Which data are electronically available on ICU's after the surgery? Observation reports (images) [c]	.36%		1.25%	.42%
Which data are electronically available on ICU's after the surgery? Electrophysiological reports [c]	.36%		1.25%	.42%
Which data are electronically available on ICU's after the surgery? Vital signs and medication [c]	.36%		1.25%	.42%
Which data are electronically available on ICU's after the surgery? Warnings [c]	.36%		1.25%	.42%
Which data are electronically available on ICU's after the surgery? Checklists [c]	.36%		1.25%	.42%
Which data are electronically available on ICU's after the surgery? Other data [c]	.36%		1.25%	.42%
Which data are available electronically for creating the discharge summary? Patient demographics [c]				1.85%
Which data are available electronically for creating the discharge summary? Case data ((coded) diagnoses and therapies) [c]				1.85%
Which data are available electronically for creating the discharge summary? Order entries [c]				1.85%
Which data are available electronically for creating the discharge summary? Observation reports (text) [c]				1.85%
Which data are available electronically for creating the discharge summary? Observation reports (images) [c]				1.85%
Which data are available electronically for creating the discharge summary? Electrophysiological reports [c]				1.85%
Which data are available electronically for creating the discharge summary? Vital signs and medication [c]				1.85%

Which data are available electronically for creating the discharge summary? Surgery reports [c]						1.85%
Which data are available electronically for creating the discharge summary? Other data [c]						1.85%
How many clinical units have stationary access (e.g. via central workplace computers) to their patient data? [d]	Distribution	4.17%	3.13%	4.17%	4.17%	4.17%
How many clinical units have mobile access (e.g. via smartphones, tablets, notebooks, computer on wheels etc.) to their patient data? [d]		4.17%	9.38%	4.17%	4.17%	4.17%
In how many clinical units is Wi-Fi available (Wi-Fi coverage)? [d]		4.17%	3.13%	4.17%	4.17%	4.17%
In how many clinical units are the following hardware devices available for documenting and processing patient data? PCs [d]		2.08%	1.17%	2.08%	2.08%	2.08%
In how many clinical units are the following hardware devices available for documenting and processing patient data? Notebooks [d]		2.08%	3.52%	2.08%	2.08%	2.08%
In how many clinical units are the following hardware devices available for documenting and processing patient data? Bedside terminals [d]		2.08%	1.17%	2.08%	2.08%	2.08%
In how many clinical units are the following hardware devices available for documenting and processing patient data? Tablets [d]		2.08%	1.17%	2.08%	2.08%	2.08%
In how many clinical units are the following hardware devices available for documenting and processing patient data? Smartphones [d]		2.08%	1.17%	2.08%	2.08%	2.08%
In how many clinical units are the following hardware devices available for documenting and processing patient data? Thin clients [d]		2.08%	1.17%	2.08%	2.08%	2.08%
Please indicate to what degree the electronic health record (EHR) is used in your hospital? [e]	Integration & Interoperability	1.74%	2.05%	1.92%	1.55%	1.58%
How are the different systems integrated with one another? [f]		1.74%	2.05%	1.92%	1.55%	1.58%
Which of the following standards/profiles are used in your HIS: HL7 V2 messages? [c]		.68%	.92%	1.07%	.72%	.63%
Which of the following standards/profiles are used in your HIS: DICOM? [c]		.68%	.92%	1.07%	.72%	.63%
Which of the following standards/profiles are used in your HIS: HL7 V3 messages? [c]		.68%	.92%	1.07%	.72%	.63%
Which of the following standards/profiles are used in your HIS: IHE profiles? [c]		.68%	.92%	1.07%	.72%	.63%
Which of the following standards/profiles are used in your HIS: HL7 CDA's? [c]		.68%	.92%	1.07%	.72%	.63%
Which of the following standards/profiles are used in your HIS: HL7 RIM? [c]		.68%	.92%	1.07%	.72%	.63%
In how many relevant subsystems / modules of your HIS are the following patient data integrated across system boundaries, i.e. available: Patient demographics? [d]		2.13%	2.40%	1.76%	1.72%	1.55%
In how many relevant subsystems / modules of your HIS are the following patient data integrated across system boundaries, i.e. available: Diagnoses? [d]		2.13%	2.40%	1.76%	1.72%	1.55%
In how many relevant subsystems / modules of your HIS are the following patient data integrated across system boundaries, i.e. available: Therapies / procedures? [d]		2.13%	2.40%	1.76%	1.72%	1.55%
Does your hospital IT system integrate a master patient index (MPI): Indexing across internal IT systems? [b]		1.90%	2.05%	1.92%	1.55%	1.23%
Does your hospital IT system integrate a master patient index (MPI): Indexing across IT systems outside of your hospital? [b]		1.90%				1.23%
(How) are data from previous care stages usually integrated in your HIS? [g]		5.49%				
How are patient data transferred to the OR system? [h]				5.46%		
How are patient data from the OR (e.g. surgery reports) transferred to the system used on regular wards? [h]			2.05%		4.66%	1.45%
How are patient data from the OR (e.g. surgery reports) transferred to the system used on ICU's? [h]			2.05%		4.66%	1.45%

Is the medical discharge summary (doctor's letter) provided electronically for outside practitioners? [i]					6.62%
Is there a workflow management system integrated in your hospitals' information system? [c]	1.74%	2.05%	2.05%	1.55%	1.45%

[a] Response options: No, and it is not yet planned either / It is planned, but implementation has not yet started / Implementation started or resources allocated / Fully implemented in at least one clinical unit / Implemented and available in … % of all relevant clinical units.

[b] Response options: No, and it is not yet planned either / It is planned, but implementation has not yet started / Implementation started or resources allocated / Fully implemented.

[c] Response options: Yes / No.

[d] Response options: in %.

[e] Response options: We haven't yet started planning the implementation of an EHR system / We are currently developing an implementation plan / We already started implementing an EHR system (partly functioning system) / We have a fully functioning EHR system.

[f] Response options: Not at all / Some systems are not integrated / Via individual interfaces / Via a communication server / Via a shared database.

[g] Response options: Not at all (paper only) / Data is manually typed in / Via E-Mail / Via a portal / Via other IT solutions.

[h] Response options: On paper / electronically via pdf file / electronically via a shared database (incomplete data) / electronically via a shared database (all relevant data).

[i] Response options: No / Yes, via E-Mail / Yes, via a portal / Yes, via other IT solutions.

Appendix Table 3: Descriptive statistics of the Workflow Composite Score (WCS) (n=232)

Score	Mean (SD)	Min.	Max.
Workflow Composite Score	55.9 (13.7)	21.9	83.3
Sub-scores			
Admission	45.3 (15.2)	14.2	83.1
Ward round	57.8 (17.2)	19.4	88.4
Pre-surgery	64.2 (12.0)	23.5	86.2
Post-surgery	61.8 (13.3)	20.7	86.6
Discharge	56.5 (12.7)	22.7	88.3

Appendix Table 4: Convergent validity and internal consistency of the measurement models with bias corrected 95% confidence intervals (CI). Please refer to Appendix table 1 for the indicator labels

Latent Variable	Indicator	Outer Loading / Weights[a] [95% CI]	Composite Reliability (CR)[a] [95% CI]	Cronbach's α[a] [95% CI]	Average Variance Extracted (AVE)[a] [95% CI]
Professionalism of Information Management (PIM)[b]	PIM_1	.78 [.69, .85]	.76 [.69, .81]	.75 [.67, .81]	.51 [.43, .58]
	PIM_2	.74 [.65, .81]			
	PIM_3	.62 [.47, .73]			
Innovation Capability: Top Management Team Support (IC TMT)	IC_TMT_1	.80 [.70, .89]	.86 [.82, .89]	.86 [.82, .89]	.52 [.44, .58]
	IC_TMT_2	.75 [.61, .85]			
	IC_TMT_3	.74 [.60, .86]			
	IC_TMT_4	.72 [.59, .82]			
	IC_TMT_5	.67 [.55, .78]			
	IC_TMT_6	.57 [.41, .69]			
Innovation Capability of the IT Department (IC ITD)	IC_ITD_1	.87 [.77, .98]	.83 [.78, .87]	.84 [.79, .87]	.51 [.42, .58]
	IC_ITD_2	.82 [.73, .92]			
	IC_ITD_3	.64 [.45, .76]			
	IC_ITD_4	.61 [.45, .71]			
	IC_ITD_5	.58 [.41, .71]			
	IC_OW_1	.82 [.73, .92]	.81 [.75, .85]	.81 [.76, .85]	.46 [.39, .53]

Organization-Wide Innovation Capability (IC OW)	IC_OW_2	.71 [.57, .81]			
	IC_OW_3	.66 [.51, .77]			
	IC_OW_4	.62 [.50, .73]			
	IC_OW_5	.57 [.42, .67]			
Perceived HIT Workflow Support (PHITS)	PHITS_1	.80 [.72, .86]	.89 [.85, .91]	.89 [.85, .91]	.61 [.53, .67]
	PHITS_2	.80 [.70, .86]			
	PHITS_3	.78 [.73, .83]			
	PHITS_4	.76 [.67, .83]			
	GITPC_5	.76 [.66, .82]			
Clinical IT-Agents (CITA)	CITA_1	.85 [.73, .96]	.75 [.65, .82]	.74 [.65, .82]	.60 [.48, .70]
	CITA_2	.70 [.55, .82]			
Structural Characteristics (SC)[c]	SC_1	.60 [.36, .80]			
	SC_2	.56 [.31, .77]			

[a] Common acceptance ranges: Outer Loadings / Weights at least > .40, recommended >.70; CR & Cronbach's α between .70 and .90; AVE > .50.

[b] Second order construct, see Appendix Table 5 for the underlying indicators.

[c] Formative measurement model.

Appendix Table 5: Convergent validity and internal consistency of lower order constructs reflecting the latent variable "Professionalism of Information Management (PIM)" with bias corrected 95% confidence intervals (CI)

Lower Order Constructs	Indicator	Outer Loading[a] [95% CI]	Composite Reliability (CR)[a] [95% CI]	Cronbach's α[a] [95% CI]	Average Variance Extracted (AVE)[a] [95% CI]	Loading[a] with Higher Order Construct PIM [95% CI]
Strategic Information Management (PIM_1)	PIM_1_S1	.84 [.80, .87]	.87 [.85, .89]	.82 [.78, .85]	.53 [.49, .58]	.88 [.84, .91]
	PIM_1_S2	.83 [.78, .87]				
	PIM_1_S3	.67 [.56, .75]				
	PIM_1_S4	.77 [.71, .83]				
	PIM_1_S5	.63 [.54, .71]				
	PIM_1_S6	.60 [.49, .68]				
Tactical Information Management (PIM_2)	PIM_2_T1	.76 [.70, .80]	.87 [.85, .90]	.82 [.77, .86]	.58 [.53, .63]	.87 [.82, .90]
	PIM_2_T2	.81 [.76, .85]				
	PIM_2_T3	.80 [.74, .85]				
	PIM_2_T4	.77 [.70, .82]				
	PIM_2_T5	.67 [.59, .74]				
Operational Information Management (PIM_3)	PIM_3_O1	.83 [.75, .88]	.83 [.78, .87]	.73 [.63, .81]	.56 [.48, .63]	.69 [.56, .77]
	PIM_3_O2	.77 [.64, .86]				
	PIM_3_O3	.65 [.55, .74]				
	PIM_3_O4	.72 [.60, .80]				

[a] Common acceptance ranges: Loadings at least > .40, recommended >.70; CR & Cronbach's α between .70 and .90; AVE > .50.

Appendix Table 6: HTMT ratios

	OGIP	IC ITD	IC TMT	IC OW	CITA	PIM	WCS	PHITS
IC ITD	.33 [.17, .47]							
IC TMT	.36 [.22, .48]	.56 [.42, .68]						
IC OW	.62 [.51, .70]	.49 [.35, .62]	.57 [.43, .70]					
CITA	.12 [.02, .26]	.29 [.17, .41]	.39 [.24, .53]	.31 [.18, .44]				
PIM	.25 [.11, .39]	.69 [.54, .80]	.70 [.60, .80]	.48 [.34, .62]	.43 [.29, .57]			
WCS	.33 [.20, .44]	.55 [.44, .64]	.51 [.40, .61]	.38 [.24, .51]	.45 [.31, .57]	.72 [.61, .81]		
PHITS	.54 [.41, .64]	.31 [.17, .44]	.40 [.24, .54]	.36 [.23, .49]	.10 [.03, .16]	.33 [.19, .47]	.49 [.37, .59]	
COU	.19 [.08, .29]	.15 [.04, .30]	.06 [.01, .08]	.24 [.12, .36]	.10 [.02, .25]	.04 [.01, .06]	.17 [.06, .30]	.13 [.05, .22]

Appendix Table 7: Total effects and total indirect effects of the structural model with bias corrected 95% confidence intervals (CI) and significance tests of the path coefficients

Path	Coefficient [95% CI]	*P* Value
Total Effects		
Innovation Capability of the IT Department (IC ITD) → Overall Goodness of Information Provision (OGIP)	.03 [-.01, .09]	.18
Innovation Capability of the IT Department (IC ITD) → Clinical IT-Agents (CITA)	.15 [.08, .25]	<.001
Innovation Capability of the IT Department (IC ITD) → Workflow Composite Score (WCS)	.31 [.15, .46]	<.001
Innovation Capability of the IT Department (IC ITD) → Perceived HIT Workflow Support (PHITS)	.13 [.06, .21]	.001
Innovation Capability: Top Management Team Support (IC TMT) → Overall Goodness of Information Provision (OGIP)	.38 [.27, .48]	<.001
Innovation Capability: Top Management Team Support (IC TMT) → Clinical IT-Agents (CITA)	.25 [.16, .36]	<.001
Innovation Capability: Top Management Team Support (IC TMT) → Professionalism of Information Management (PIM)	.59 [.47, .70]	<.001
Innovation Capability: Top Management Team Support (IC TMT) → Workflow Composite Score (WCS)	.38 [.27, .50]	<.001
Innovation Capability: Top Management Team Support (IC TMT) → Perceived HIT Workflow Support (PHITS)	.30 [.21, .40]	<.001
Organization-Wide Innovation Capability (IC OW) → Overall Goodness of Information Provision (OGIP)	.59 [.46, .71]	<.001
Organization-Wide Innovation Capability (IC OW) → Perceived HIT Workflow Support (PHITS)	.22 [.07, .37]	.01
Clinical IT-Agents (CITA) → Overall Goodness of Information Provision (OGIP)	.02 [.00, .06]	.23
Clinical IT-Agents (CITA) → Perceived HIT Workflow Support (PHITS)	.07 [.01, .15]	.03
Professionalism of Information Management (PIM) → Overall Goodness of Information Provision (OGIP)	.06 [-.02, .17]	.17
Professionalism of Information Management (PIM) → Workflow Composite Score (WCS)	.55 [.36, .74]	<.001
Professionalism of Information Management (PIM) → Perceived HIT Workflow Support (PHITS)	.23 [.10, .42]	.01
Structural Characteristics (SC) → Overall Goodness of Information Provision (OGIP)	.16 [.09, .23]	<.001
Structural Characteristics (SC) → Innovation Capability of the IT Department (IC ITD)	.19 [.11, .27]	<.001
Structural Characteristics (SC) → Organization-Wide Innovation Capability (IC OW)	.19 [.12, .27]	<.001
Structural Characteristics (SC) → Clinical IT-Agents (CITA)	.23 [.15, .33]	<.001
Structural Characteristics (SC) → Professionalism of Information Management (PIM)	.55 [.44, .65]	<.001
Structural Characteristics (SC) → Workflow Composite Score (WCS)	.46 [.34, .56]	<.001
Structural Characteristics (SC) → Perceived HIT Workflow Support (PHITS)	.23 [.17, .31]	<.001
Workflow Composite Score (WCS) → Overall Goodness of Information Provision (OGIP)	.10 [.00, .23]	.14
Country (COU) → Overall Goodness of Information Provision (OGIP)	.15 [.08, .22]	<.001

Country (COU) → Clinical IT-Agents (CITA)	.02 [.00, .05]	.07
Country (COU) → Professionalism of Information Management (PIM)	.05 [.01, .10]	.06
Country (COU) → Workflow Composite Score (WCS)	.17 [.03, .31]	.01
Country (COU) → Perceived HIT Workflow Support (PHITS)	.12 [.06, .18]	<.001
Total indirect effects		
Innovation Capability: Top Management Team Support (IC TMT) → Professionalism of Information Management (PIM)	.21 [.11, .33]	<.001
Innovation Capability: Top Management Team Support (IC TMT) → Workflow Composite Score (WCS)	.41 [.25, .62]	<.001
Innovation Capability of the IT Department (IC ITD) → Workflow Composite Score (WCS)	.20 [.08, .41]	.03
Organization-Wide Innovation Capability (IC OW) → Overall Goodness of Information Provision (OGIP)	.10 [.04, .18]	.01
Organization-Wide Innovation Capability (IC OW) → Perceived HIT Workflow Support (PHITS)	.01 [-.07, .90]	.78
Professionalism of Information Management (PIM) → Workflow Composite Score (WCS)	.08 [.02, .16]	.04
Structural Characteristics (SC) → Professionalism of Information Management (PIM)	.20 [.12, .28]	<.001
Structural Characteristics (SC) → Workflow Composite Score (WCS)	.32 [.19, .49]	<.001
Workflow Composite Score (WCS) → Overall Goodness of Information Provision (OGIP)	.18 [.11, .29]	<.001
Country (COU) → Workflow Composite Score (WCS)	.05 [-.01, .10]	.10

Appendix Table 8: Direct path coefficients with bias corrected 95% confidence intervals (CI), significance tests of path coefficients and their effect sizes

Path	Coefficient [95% CI]	*P* Values	f^2
Innovation Capability of the IT Department (IC ITD) → Professionalism of Information Management (PIM)	.36 [.20, .51]	<.001	.31
Innovation Capability of the IT Department (IC ITD) → Workflow Composite Score (WCS)	.10 [-.14, .31]	.37	.01
Innovation Capability: Top Management Team Support (IC TMT) → Innovation Capability of the IT Department (IC ITD)	.58 [.43, .70]	<.001	.53
Innovation Capability: Top Management Team Support (IC TMT) → Organization-Wide Innovation Capability (IC OW)	.58 [.44, .70]	<.001	.54
Innovation Capability: Top Management Team Support (IC TMT) → Professionalism of Information Management (PIM)	.38 [.23, .53]	<.001	.33
Innovation Capability: Top Management Team Support (IC TMT) → Workflow Composite Score (WCS)	-.02 [-.26, .17]	.84	.01
Organization-Wide Innovation Capability (IC OW) → Overall Goodness of Information Provision (OGIP)	.50 [.37, .62]	<.001	.39
Organization-Wide Innovation Capability (IC OW) → Perceived HIT Workflow Support (PHITS)	.21 [.06, .36]	.01	.06
Organization-Wide Innovation Capability (IC OW) → Workflow Composite Score (WCS)	.03 [-.17, .22]	.78	.01

Clinical IT-Agents (CITA) → Workflow Composite Score (WCS)	.18 [.02, .33]	.02	.06
Moderating Effect (IC OW) → Overall Goodness of Information Provision (OGIP)	.21 [.08, .35]	.008	.09
Professionalism of Information Management (PIM) → Clinical IT-Agents (CITA)	.43 [.29, .57]	<.001	.22
Professionalism of Information Management (PIM) → Workflow Composite Score (WCS)	.48 [.31, .69]	<.001	.28
Structural Characteristics (SC) → Innovation Capability: Top Management Team Support (IC TMT)	.33 [.21, .43]	<.001	.12
Structural Characteristics (SC) → Professionalism of Information Management (PIM)	.35 [.24, .47]	<.001	.39
Structural Characteristics (SC) → Workflow Composite Score (WCS)	.13 [-.07, .31]	.19	.02
Workflow Composite Score (WCS) → Overall Goodness of Information Provision (OGIP)	-.06 [-.21, .07]	.33	.01
Workflow Composite Score (WCS) → Perceived HIT Workflow Support (PHITS)	.42 [.29, .54]	<.001	.21
Perceived HIT Workflow Support (PHITS) → Overall Goodness of Information Provision (OGIP)	.44 [.28, .58]	<.001	.28
Country (COU) → Innovation Capability of the IT Department (IC ITD)	.13 [.01, .25]	.03	.03
Country (COU) → Organization-Wide Innovation Capability (IC OW)	.22 [.10, .34]	<.001	.08
Country (COU) → Workflow Composite Score (WCS)	.14 [.01, .26]	.04	.04

Declaration of Originality and Contributions

I hereby declare that I have carried out this work without inadmissible help from third parties and without using other aids than those indicated. The data and concepts taken directly or indirectly from other sources are marked with reference to the respective source.

The following people have directly or indirectly contributed to the thesis free of charge:

1. Development of the initial scale sets: Prof. Dr. Jan Liebe and Prof. Dr. Ursula Hübner in particular. Furthermore, the members of the *Health Informatics Research Group* at the University of Applied Sciences Osnabrück conducted pretests of the scale sets and provided feedback on possible modifications. Additional information on this can be found in chapter 3.2.
2. Data Collection: Maria Hasselbach in helping to research the various contact data for carrying out the surveys across Austria, Germany, and Switzerland.
3. Data Storage: Dr. Jan-Patrick Weiß and Dr. Jens Rauch developed the data warehouse in which the data were stored, and Jörg Haßmann and Jens Schulte provided the corresponding server.
4. The co-authors of the five papers to the extent described below: Jens Hüsers (JH)[24], Prof. Dr. Ursula Hübner (UH)[1], Prof. Dr. Elske Ammenwerth (EA)[25], Dr. Werner Hackl (WH)[2], Laura Naumann (LN)[1], Prof. Dr. Jan-David Liebe (JDL)[1,2], Dr. Jan-Patrick Weiß (JW)[1], Prof. Dr. Birgit Babitsch (BB)[26], Franziska Jahn (FJ)[27], Prof. Dr. Alfred Winter (AW)[4] & Dr. Johannes Thye (JT)[1].

Publication 1: Innovative Power of Health Care Organisations Affects IT Adoption: A bi-National Health IT Benchmark Comparing Austria and Germany

Authors	JH	UH	**ME**	EA	WH	LN	JDL
Concept	X	X	X				X
Literature search	X	X	X			X	
Methods	X	X	X	X	X		X
Data collection	X	X		X			X
Data analysis	X		X				
Writing	X	X	X			X	
Revision	X	X	X	X	X	X	X

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Jens Hüsers, as the first author, contributed to all steps of the development of the paper (except for the design of the questionnaire) and was primarily responsible for performing the statistical analyses.

Ursula Hübner, as the supervisor, was primarily involved in the conceptualization (both in terms of contents and methodology), data collection, and writing.

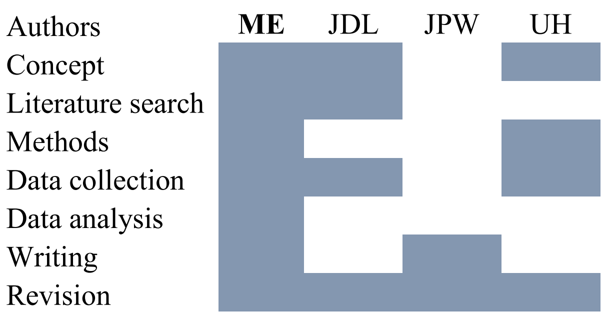
Moritz Esdar contributed to all steps of the paper development except for the questionnaire design and data collection. In the conceptualization, he primarily contributed to the analysis with regard to the role of innovative power.

Elske Ammenwerth and **Werner Hackl** supported the development of the methods and the data collection. They also revised the manuscript.

Laura Naumann provided support in the literature search and writing of the manuscript.

Jan-David Liebe was co-responsible for the conceptualization (in terms of contents and methodology) and the main person responsible for the data collection.

Publication 2: Exploring Innovation Capabilities of Hospital CIOs: An Empirical Assessment



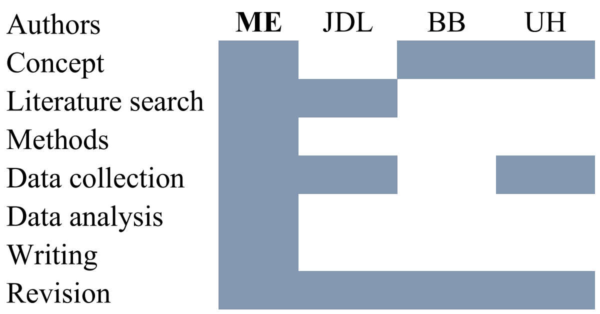
Moritz Esdar, as the first author, was responsible for all steps of the publication's development – except for the data collection, which he only assisted.

Jan-David Liebe was responsible for the data collection and contributed to the conceptualization of the question items.

Jan-Patrick Weiß assisted with drafting the manuscript and contributed to the revisions.

Ursula Hübner supervised the work and contributed to the conceptualization with regard to contents and methodology.

Publication 3: Determinants of Clinical Information Logistics: Tracing Socio-Organisational Factors and Country Differences from the Perspective of Clinical Directors



Moritz Esdar, as the first author, was responsible for all steps of the publication's development.

Jan-David Liebe contributed to the literature search and the revisions.

Birgit Babitsch and **Ursula Hübner** supervised the work, thereby contributing particularly to the conceptualization.

Publication 4: Professionalism of Information Management in Health Care: Development and Validation of the Construct and Its Measurement

Authors	JT	**ME**	JDL	FJ	AW	UH
Concept	■	■	■	■	■	■
Literature search	■					
Methods	■	■	■			■
Data collection	■	■	■			■
Data analysis	■	■				
Writing	■	■				■
Revision	■	■	■	■	■	■

Johannes Thye, as the first author, contributed to all parts of the paper's development and was primarily responsible for writing.

Moritz Esdar contributed to all parts of the development except for the literature search and was responsible for the methods and data analyses.

Jan-David Liebe particularly contributed to the concept (with regard to both contents and methods) and assisted with the data collection.

Franziska Jahn and **Alfred Winter** contributed to the concept and the manuscript revisions.

Ursula Hübner supervised the work and contributed to almost all parts of the paper's development.

Publication 5: The Effect of Innovation Capabilities of Health Care Organizations on the Quality of Health Information Technology: Model

Authors	**ME**	UH	JT	BB	JDL
Concept	■	■		■	■
Literature search	■		■		■
Methods	■	■		■	
Data collection	■	■	■		
Data analysis	■				
Writing	■				
Revision	■	■	■	■	■

Moritz Esdar was responsible for all parts of the publication's development.

Ursula Hübner, as supervisor, contributed particularly to the conceptualization and provided support to the data collection and to the manuscript revisions.

Johannes Thye supported the literature search and data collection.

Birgit Babitsch supervised the work and contributed to the conceptualization as well as to the manuscript revisions.

Jan-David Liebe contributed to the conceptualization, the literature search, and the revisions.

No other persons or organizations were involved in the production of this thesis. In particular, I have not made use of the paid assistance of consulting services, doctoral advisors, or other persons. No one has directly or indirectly received monetary benefits from me for work related to the content of the submitted dissertation.

The thesis has not been submitted to any other examination authority in the same or a similar form, neither in Germany nor abroad.

Osnabrück, 10/01/2022 ....

Moritz Esdar