Benchmarking
Complex eHealth Innovations

Konzeption, Entwicklung und Umsetzung einer skalierbaren Austauschplattform zur Unterstützung innovativer eHealth-Strategien in Krankenhäusern

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Inhaltsverzeichnis

Abkürzungsverzeichnis

AKG	Arbeitsgruppe IT der Arbeitsgemeinschaft kommunaler Groß-Krankenhäuser
ALKRZ	Arbeitskreis der Leiter der Klinischen Rechenzentren der Universitätskliniken
CIO	Chief Information Officer
CIRS	Critical Incidence Reporting
CPOE	Computerized Physician Order Entry
FAMI	Fachausschuss für Medizinische Informatik
GMDS	Deutschen Gesellschaft für Medizinische Informatik, Biometrie und Epidemiologie e.V.
ITIL	IT Infrastructure Library
KH-IT	Bundesverband der Krankenhaus-IT-Leiterinnen/Leiter KH-IT e.V.
KHL	Krankenhausleitung
KIS	Krankenhausinformationssystem
KPI	Key-Performance-Indikator
MPI	Master Patient Index
PACS	Picture Archiving and Communication System
PDL	Pflegedienstleitung
VHB	Verband der Hochschullehrer für Betriebswirtschaft
WCS	Workflow Composite Score
WKWI	Wissenschaftliche Kommission Wirtschaftsinformatik

Abbildungsverzeichnis

Tabellenverzeichnis

Teil A – Dachbeitrag

1 Ausgangssituation

„Les lois de l'imitation" (Gesetze der Nachahmung) (De Tarde 1870) - bereits der Titel dieses 1870 erschienenen Werkes über die Verbreitung von Innovationen lässt sich als Hinweis auf die innovationsfördernde Wirkung von Benchmarkings deuten. Die synoptische Gegenüberstellung zu Mains' frühen Benchmarking-Definition unterstreicht diesen Zusammenhang: *„[Benchmarking is] the art of finding out, in a perfectly legal and aboveboard way, how others do something better than you do - so you can imitate - and perhaps improve upon - their techniques"* (Main 1992, S. 106). Im Kontext zunehmender Digitalisierungstendenzen steigt seither der branchenübergreifende Bedarf, IT-basierte Prozess- und Serviceinnovationen durch imitierende Verhaltensweisen zu realisieren (Sambamurthy et al. 2003, Swanson 1994)[1]. Dies gilt in besonderer Weise für Krankenhäuser, die sich in einem zunehmenden Wettbewerb um die effizienteste Leistungserbringung, die höchste Versorgungsqualität und die ansprechendsten Services befinden (Simon 2016)[2]. eHealth-Technologien tangieren aufgrund ihrer vielfältigen Vernetzungs-, Automatisierungs- und Datennutzungspotenziale die Kompetitivität der Einrichtungen in jedem dieser Wettbewerbsfelder (Rasche 2017)[3].

Bereits im Rahmen des gesetzgeberisch intendierten Kostenwettbewerbs, der die Krankenhäuser zu einem optimierten Kapazitätsmanagement und einer Verschlankung von Zentral- und Supportbereichen anhält, ermöglichen eHealth-Anwendungen die Identifikation und Nutzung vielfältiger Effizienzreserven (Buntin et al. 2011). Angefangen mit dem administrativen Bereich, in dem elektronische Patientenaktenakten (EPA) das digitale Fall-Handling und somit die Erlössicherung durch das Medizincontrolling vereinfachen (Denton et al. 2007), zeigen sich vor allem in klinischen Sekundärprozessen Potenziale für ein optimiertes Ressourcenmanagement (Chaudhry et al. 2006, Goldzweig et al. 2009, Jones et al. 2014). Diese beziehen sich sowohl auf planende Aktivitäten, indem bspw. das OP- oder das Belegmanagement durch ständig verfügbare Auslastungs- und Statusinformationen vereinfacht werden (Denton et al. 2007), als auch auf logistische Prozesse, indem Bestell- und Liefervorgänge aus der Radiologie, dem Labor oder der Kardiologie automatisiert werden (Appari et al. 2014).

Aber auch innerhalb des Qualitätswettbewerbs, der als harmonisierende Zielgröße zum Kostenwettbewerb eine sichere und hochwertige Patientenversorgung fokussiert (Rasche 2017), versprechen eHealth-Technologien weitreichende Qualitätssprünge in Richtung einer fehlerfreien, kontinuierlichen und patientenzentrierten Versorgung (Burke et al. 2005). So können einerseits Monitoring- und Trackingfunktionen unerwünschte Ereignisse im Behandlungsverlauf frühzeitig erkennen und über Alarmfunktionen anzeigen (Bates und Gawande 2003). Andererseits ermöglichen mobile Endgeräte die ständige Verfügbarkeit medizinischer Wissensdatenbanken bzw. evidenzbasierter Schlüsselinformationen zu Diagnosen, Medikation und Therapie am Point of Care (Lenz und Reichert 2007). Während krankenhausintern elektronische Kurven und Übergabeakten den Weg zu einer patientenzentrierten und kontinuierlichen Versorgung ebnen (Flemming und Hübner 2013), lassen sich einrichtungsübergreifend ähnliche Effekte durch den Einsatz elektronischer Arzt-, Pflege- und Wundberichte erzielen (Hübner et al. 2015). Schließlich können eHealth-Anwendungen den Behandlungszugang erleichtern, indem bspw.

[1] In diesem Kontext können Innovationen als Veränderungen von Produkten, Prozessen und Dienstleistungen definiert werden, die sich durch die Nutzung von IT ergeben (Rogers 2010). Innovationen sind dabei kein Selbstzweck, sondern stehen immer in Verbindung mit einer beabsichtigten Performancesteigerung (insb. Effizienz- und Effektivitätssteigerungen)(OECD 2005).

[2] Eine ausführliche und chronologische Betrachtung von Ökonomisierungstendenzen innerhalb der deutschen Krankenhauslandschaft findet sich in Simon (2016).

[3] Der Begriff „eHealth" umfasst alle Anwendungen des integrierten Einsatzes von Informations- und Kommunikationslösungen im Gesundheitswesen zur Überbrückung von Raum und Zeit (Fischer 2016).

über Tele-Konsile ortsunabhängig Expertenmeinungen eingeholt werden (Mary Jo Gorman MD 2011), über Tele-Notarztsysteme die Zeit von der Aufnahme im Rettungswagen bis zur OP verkürzt wird (Reinke et al. 2012) oder über webbasierte Service-Apps auch schwer zugängliche Patientengruppen erreicht werden (z.B. bei Essstörungen, Alkohol- oder Drogenmissbrauch) (Gerhardt et al. 2015). Trotz dieser vielfältigen und gleichzeitig wettbewerbskritischen *digital options* (Sambamurthy et al. 2003), existieren zahlreiche Berichte über gescheiterte Implementierungsprojekte (Spetz 2009), schwer nachweisbare Effizienz- und Effektivitätssteigerungen (Greenhalgh et al. 2009), adverse bzw. negative Anwendungsfolgen (Black et al. 2011) und, ganz allgemein, über einen vermeintlichen Digitalisierungsrückstand des Krankenhauswesens im Branchenvergleich (Agarwal et al. 2010). Zur Erklärung dieser widersprüchlichen Situation lassen sich aus der *Diffusion of Innovation Theory* (Rogers 2010) sowie verwandten Theorieansätzen, drei Grundannahmen über die Verwirklichung digitaler Wettbewerbsoptionen in Krankenhäusern ableiten[4]:

1.) In Krankenhäusern wird die Realisierung digitaler Wettbewerbsoptionen sowohl von der Anzahl, als auch von der Homogenität erfolgskritischer IT-Stakeholder determiniert. Die Entscheidung zur Annahme oder Ablehnung einer Innovation wird nach Rogers (2010) auf Ebene des Individuums getroffen. Entsprechend ist jedes Krankenhausmitglied ein erfolgskritischer IT-Stakeholder, das die Beschaffung von eHealth initiiert, implementiert oder im Arbeitsalltag mit den neuen Technologien interagiert. Es gilt: Je größer die Anzahl innovationsfreudiger IT-Stakeholder, desto größer die Umsetzungschancen von eHealth-Innovationen. Diese einfache Gleichung verkompliziert sich allerdings unter Hinzunahme netzwerktheoretischer Perspektiven. Demnach verbreiten sich Innovationen in geschlossenen Gruppen besonders schnell und nachhaltig, wenn ihre Mitglieder gemeinsame Charakteristika aufweisen. Heterogene Gruppenkonstellationen verlangsamen die Verbreitung hingegen (Rogers 2010). Gerade Krankenhäuser gelten jedoch als hoch fragmentierte, von starren Hierarchien und einer hohen berufsständischen Autonomie geprägte *Siloorganisationen* (Genzel und Siess 1999, Leuzinger und Luterbacher 2000). Entsprechend oft gehören erfolgskritische IT-Stakeholder unterschiedlichen Professionen, Hierarchieebenen, Fachabteilungen oder auch Einrichtungen an[5, 6].

2.) In Krankenhäusern erfordert die Realisierung digitaler Wettbewerbsoptionen tiefgreifende, weitreichende und langfristige Umwandlungsprozesse. Die Adoption von Innovationen ist keine spontane Reaktion, sondern ein sozialer Prozess (Rogers 2010). Aus diesem Grund erfordert auch die Umsetzung von eHealth-Innovationen mehr als nur die Beschaffung, Entwicklung und Installation neuer Hard- und Softwareprodukte. Auf der einen Seite müssen Krankenhäuser fortlaufend neue und strategiekonforme IT-Lösungen identifizieren (Lenz und Reichert 2007)[7]. Auf der anderen Seite müssen diese Technologien sorgfältig in die Krankenhausabläufe integriert werden (Ammenwerth et al. 2006). Hierbei stellt die Wahrung des Patientenwohls eine ebenso große Herausforderung dar, wie die oftmals schwer standardisierbaren, wissens- und erfahrungsintensiven Expertenprozesse (Lenz und Reichert 2012, Cresswell, 2011).

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[4] Neben der *Diffusion of Innovation Theory* werden diverse andere Theorien und Modelle zur Erklärung von eHealth Innovationen angewendet. Beispiele hierfür sind die *Social Contagion Theory* oder *Nolan's Six-stage Model*. Eine umfassende Übersicht geben Greenhalgh et. al (2004) sowie Cresswell und Sheikh (2013).

[5] Nach Mantzana et al. (2007) beteiligen sich bei der Umsetzung von eHealth-Innovationen in Krankenhäusern bis zu 15 IT-Stakeholdergruppen.

[6] Die Umsetzung von eHealth-Innovationen kann somit insbesondere dann zögerlich verlaufen, wenn interdisziplinäre, abteilungs- oder einrichtungsübergreifende Abläufe unterstützt werden sollen, eHealth-Innovationen ausschließlich zentral von der Krankenhausleitung oder dezentral auf Anwenderebene initiiert werden oder die neuen Technologien nach einer abteilungsinternen Pilotierung in den krankenhausweiten Rollout gehen (Ammenwerth et al. 2006, Spetz 2009, Goh et al. 2011).

[7] Aufgrund des rasanten medizinischen und technologischen Fortschritts sehen sich die Krankenhäuser gerade in Bezug auf eHealth-Anwendungen einem zunehmenden „Technology Push“ ausgesetzt (Stichworte: „Medizinische Wissensexplosion“, „Medizin 4.0“) (Lenz and Reichert 2012, Rasche 2017).

3.) In Krankenhäusern wird die Realisierung digitaler Wettbewerbsoptionen von einem komplexen Geflecht technischer, organisatorischer und sozialer Faktoren determiniert. Nach Rogers (2010) beeinflussen sowohl die Eigenschaften der Innovation als auch die des Innovators den Erfolg von Adoptionsprozessen. Entsprechend wird auch die Umsetzung von eHealth-Innovationen durch ein komplexes Geflecht technischer, organisatorischer und kultureller Faktoren determiniert (Cresswell und Sheikh 2013). Frühere Studien über Erfolgsfaktoren von eHealth-Innovationen fokussierten dabei vor allem technische Merkmale. Chaudhry fasst die Ergebnisse wie folgt zusammen: *„All the systems were multifunctional [...] and all had capabilities added incrementally over several years"* (Chaudhry et al. 2006, S.744). Neue Technologien, wie bspw. Wearables, Smartglasses oder entscheidungsunterstützende Funktionen entfalten ihre innovative Wirkung demnach erst, wenn sie Teil eines integrierten, interoperablen und zumeist evolutionär gewachsenen Krankenhausinformationssystems (KIS) sind (Hübner 2015). Neben technischen Merkmalen fokussieren jüngere Adoptionsstudien zunehmend auch soziale und organisatorische Faktoren als erfolgskritische Determinanten (Buntin et al. 2011). Insbesondere drei Bereiche erscheinen hierbei relevant: Erstens, das Vorhandensein eines professionellen IT-Managements, das durch planende, durchführende und überprüfende Aktivitäten die Umsetzung von eHealth-Innovationen optimal begleitet (Haux et al. 2013). Zweitens, ausgeprägte IT-Governancestrukturen, welche die Handlungsfähigkeit des IT-Managements unter anderem durch ausreichende Entscheidungsbefugnisse und Budgetverfügungen sicherstellt (Thatcher et al. 2013). Und drittens, eine ausgeprägte Innovationskultur, die das IT-Management - ergänzend zur IT-Governance - durch eine visionäre Ausrichtung, einem hohen Intrapreneurship und einer kooperativen Zusammenarbeit zwischen den IT-Stakeholdern unterstützt (Leidner et al. 2010, (Bradley et al. 2012).

Zusammenfassend kann festgehalten werden, dass sich digitale Wettbewerbsoptionen in Krankenhäusern nur in Form *komplexer eHealth-Innovationen* (Hübner 2015) verwirklichen lassen. Die Einrichtungen müssen somit vor allem inkrementelle Innovationsstrategien verfolgen, wenn sie ihre IT-Landschaft proaktiv und wettbewerbsorientiert gestalten wollen (Leidner et al. 2010)[8]. Damit die IT-Verantwortlichen hierbei die richtigen Entscheidungen treffen können, benötigen sie fortlaufend gute und umfassende Informationen (Avgar et al. 2012). Vor allem drei Fragen gilt es dabei zu beantworten: (1.) Wo stehen wir mit unserer IT und inwiefern haben wir unsere strategischen IT-Ziele bereits erreicht (Status Quo)? (2.) Wo müssen wir uns noch verbessern, auch im Vergleich zu unseren Mitbewerbern (Schwachstellenanalyse) und (3.) wie können wir uns verbessern bzw. was sind die Best Practices?

Wie bereits einleitend beschrieben, haben sich Benchmarks zur Beantwortung dieser Fragen bewährt (Legner 2013). So können Benchmarkings nach Camp (1992) durch einen systematischen, kontinuierlichen und konstruktiven Austausch mit ähnlichen Organisationen Optimierungspotenziale aufdecken und Best Practices identifizieren. Besonders vielversprechend erscheint der Einsatz dabei in solchen Bereichen, in denen ein Innovationsgefälle zwischen den Branchenteilnehmern existiert. Hier können Benchmarkings im Sinne institutionalisierter Kommunikationskanäle einen kontinuierlichen Austausch zwischen Branchenteilnehmern erleichtern und somit *Leapfrogging-Optionen* schaffen (Drew 1997, Rogers 2010)[9]. Abbildung 1 verdeutlicht das Unterstützungspotenzial von Benchmarks am Beispiel der Realisierung komplexer eHealth-Innovationen.

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[8] Gegenüber disruptiven Innovationsstrategien wird bei inkrementellen Innovationsstrategien eine schrittweise, stetige und vergleichsweise risikoarme Optimierung des Krankenhausinformationssystems (KIS) angestrebt (Drew 1997).

[9] Nach Rogers (2010) wird die Intensität der Verbreitung von Innovationen nicht nur durch die Eigenschaften der Innovation und des Innovators determiniert, sondern auch von verfügbaren Kommunikationskanälen bestimmt, indem diese eine räumliche Vernetzung bzw. den Informationsaustausch zwischen den Beteiligten eines sozialen Systems erleichtern. Leapfrogging bezeichnet das Auslassen einzelner Stufen im Laufe eines Entwicklungsprozesses (Kaulfus 2007).

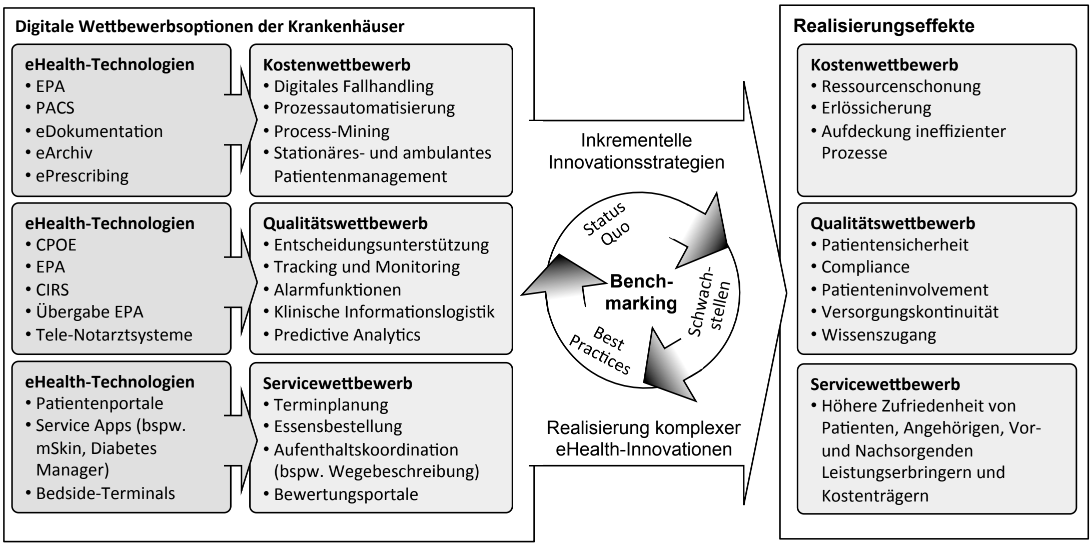

Abbildung 1. Benchmarkings als Unterstützungsinstrument inkrementeller Innovationsstrategien

2 Motivation und Zielsetzung

Wie im vorangegangenen Kapitel am Beispiel der Krankenhäuser dargestellt, besitzen Benchmarks ein hohes Potenzial, die Realisierung IT-basierter Prozess- und Serviceinnovationen zu unterstützen. Gleichzeitig stellt der zumeist inkrementelle, komplexe und kontingente Charakter solcher Innovationen spezifische Anforderungen an die Durchführung der Verfahren. Zuvorderst sind hierbei die Herausforderungen einer räumlichen, zeitlichen und inhaltlichen Skalierbarkeit zu nennen:

Räumliche Skalierbarkeit: Innovationen sind relative Phänomene (Rogers 2010). Die Frage, wie innovativ ein Benchmarking-Teilnehmer ist, lässt sich somit nur im Rahmen passender Vergleichsgruppen feststellen. Gleichzeitig müssen diese *Peergroups* immer auch möglichst viele Benchmarking-Teilnehmer umfassen, damit signifikante bzw. repräsentative Vergleiche erzielt werden können (Bortz und Döring 2007, Kütz 2013). Am Beispiel der Krankenhäuser lässt sich diese Herausforderung konkretisieren. So existiert zwar mit 1956 Einrichtungen in Deutschland eine Vielzahl potenzieller Benchmarking-Partner, allerdings handelt es sich hierbei um sehr heterogene Organisationen, die sich unter anderem in ihrer Größe, Trägerschaft und Fachrichtung voneinander unterscheiden (Statistisches Bundesamt 2015). Erst, wenn im Hinblick auf solche Unterscheidungsmerkmale eine ausreichend große Vergleichsgruppe identifiziert wird, können auch Ursache- und Wirkungszusammenhänge vergleichbar erfasst werden. Die Anforderung einer räumlichen Skalierbarkeit geht somit immer auch mit der Anforderung an ein statistisches Benchmarking einher (Kütz 2013).

Zeitliche Skalierbarkeit: Inkrementelle IT-Innovationen entwickeln sich zumeist evolutionär über einen längeren Zeitraum, wie unter Kapitel 1 am Beispiel komplexer eHealth-Innovationen dargestellt (vgl. Grundannahme 2). Statistische Benchmarks, die komplexe IT-Innovationen fokussieren, müssen somit immer auch langfristig und regelmäßig angelegt sein. Nur so lassen sich auf Basis longitudinaler Trend- oder Panelstudien inkrementelle Entwicklungen valide erfassen und Ursache-Wirkungsbeziehungen überzufällig erklären (Bortz und Döring 2007).

Inhaltliche Skalierbarkeit: Die erfolgreiche Realisierung IT-basierter Prozess- und Serviceinnovationen ergibt sich oft in Form einer technischen und sozialen Evolution, die sowohl durch Unwägbarkeiten, als auch durch Fehler und Zufälle gekennzeichnet ist (vgl. Kapitel 1)

(Frank 2009). Gleichzeitig werden die Lebenszyklen existierender Anwendungen zunehmend kürzer und auch der Markteintritt neuer Technologien erfolgt im Sinne disruptiver Innovationen in immer kürzer werdenden Abständen (Rasche 2017). Damit statistische Benchmarks diese kontingenten und gleichzeitig dynamischen Entwicklungen berücksichtigen können, braucht es kalibrierbare Erhebungsinstrumente, die im Verlauf der Benchmarking-Runden kontinuierlich angepasst werden können.

Neben den spezifischen Anforderungen eines skalierbaren Verfahrens, ist die Durchführung von Benchmarkings immer auch mit organisatorischen Herausforderungen verbunden, wobei sich insbesondere die Datenerhebung und -auswertung als äußerst ressourcenintensiv herausstellen kann (Drew 1997, Teuteberg et al. 2009). Schließlich sind Benchmarkings auf eine möglichst wissenschaftliche Durchführung angewiesen, damit eine valide und unabhängige Erhebung und Rückspiegelung der Informationen gewährleistet werden kann (Kütz 2013).

Die vorliegende Arbeit verfolgt zwei Ziele: Zum einen soll eine skalierbare Benchmarkingplattform zur Unterstützung inkrementeller Innovationsstrategien konzipiert und entwickelt werden. Zum anderen soll die Plattform am Beispiel der Krankenhäuser und im Hinblick auf komplexe eHealth-Innovationen umgesetzt werden. Die Entwicklung und Umsetzung basiert dabei auf der Annahme eines *innovationskatalytischen Prinzips*, welches als Arbeitshypothese vorgeschlagen wird. Das Prinzip geht davon aus, dass zwischen der Unternehmenspraxis einerseits und der Forschung andererseits ein grundsätzliches Anreizverhältnis für einen wechselseitigen Informationsaustausch besteht. Dies lässt sich am Beispiel der Krankenhäuser verdeutlichen: Während auf der einen Seite IT-verantwortliche Entscheidungsträger fortwährend daran interessiert sind, valide und gesicherte Informationen über die Verwirklichung komplexer eHealth-Innovationen zu erhalten (insb. Status Quo, Schwachstellenanalyse, Best Practices, vgl. Kapitel 1), sind auf der anderen Seite Forscher der Wirtschaftsinformatik und der Medizinischen Informatik daran interessiert, kontinuierlich empirische Daten und Informationen zur Beschreibung und Erklärung solcher Innovationen zu generieren (Rohner und Winter 2008). Wird auf Basis dieses Anreizverhältnisses eine Benchmarkingplattform umgesetzt, können Netzwerkeffekte entstehen, die wiederum die geforderte Skalierbarkeit des Verfahrens begünstigen[10]: Wird das Benchmarking im Zeitverlauf zunehmend mehr genutzt, kann (1.) das entscheidungsunterstützende Informationsangebot für die Teilnehmer fortlaufend optimiert werden (bspw. durch die Möglichkeit von Trendanalysen bei langjähriger Teilnahme), (2.) der wissenschaftliche Erkenntnisstand kontinuierlich angereichert werden (insb. durch die Möglichkeit der empirischen Überprüfung von Hypothesen, Modellen und Theorien) und (3.) das Verfahren selber fortlaufend weiterentwickelt werden (durch den anhaltenden Rückgriff auf praktische Anforderungen einerseits und den aktuellen wissenschaftlichen Erkenntnisstand andererseits). In Abbildung 2 wird das *innovationskatalytische Prinzip* am Beispiel komplexer eHealth-Innovationen verdeutlicht.

Um die Wirkungsweise des Prinzips zu testen, soll die Benchmarkingplattform am Beispiel der Krankenhäuser umgesetzt werden. Wie in Kapitel 1 gezeigt, stellt das Krankenhauswesen ein besonders vielversprechendes Anwendungsgebiet solcher Verfahren dar (vgl. Kapitel 1)[11]. Die Konstruktion der Plattform soll sich in besonderer Weise an der *Diffusion of Innovation Theory*, sowie an verwandten Theorieansätzen und dem aktuellen empirischen Erkenntnisstand über die Verbreitung von eHealth-Innovationen orientieren. Vor dem Hintergrund der in Kapitel 1 formulierten Grundannahmen soll das Verfahren insbesondere alle erfolgskritischen IT-

[10] Netzwerkeffekte beschreiben, wie sich der Nutzen aus einer Dienstleistung für einen Konsumenten ändert, wenn sich die Anzahl anderer Konsumenten derselben Dienstleistung ändern. Der Nutzen für den jeweiligen Konsumenten ist demnach abhängig von der gesamten Nutzerzahl. Ein Netzwerk kann informationsökonomisch als eine Zusammenfassung von Nutzern einer bestimmten Dienstleistung bezeichnet werden (Dietl und Royer 2000).

[11] Benchmarkings sind den Krankenhäusern nicht unbekannt. Beispielsweise nutzen der KH-IT e.V., der ALKRZ und die AKG entsprechende Verfahren für einen krankenhausübergreifenden Erfahrungsaustausch (Jahn et al. 2015). Aufgrund der beschriebenen methodischen und organisatorischen Anforderungen erscheinen sich diese Initiativen jedoch nur bedingt für das Benchmarking komplexer eHealth-Innovationen zu eignen.

Stakeholder fokussieren (Grundannahme 1), den inkrementellen bzw. evolutionären Charakter komplexer eHealth-Innovationen berücksichtigen (Grundannahme 2) und neben der technischen Ebene auch organisatorische Rahmenbedingungen adressieren (Grundannahme 3).

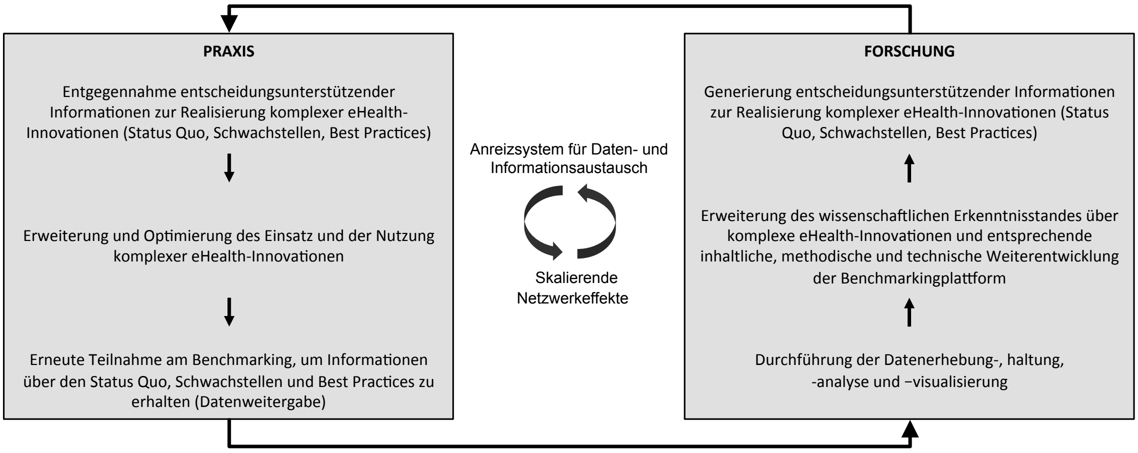

Abbildung 2: Skalierbare Benchmarkingplattform auf Basis eines innovationskatalytischen Prinzips

3 Einordnung

Ausgehend von der in Kapitel 2 dargestellten Zielsetzung lässt sich die vorliegende Arbeit an der interdisziplinären Schnittstelle zwischen Wirtschaftsinformatik und Medizinischer Informatik einordnen. Obwohl der Ursprung beider Disziplinen in der Informatik liegt (Loos et al. 2013), grenzen sich die Wirtschaftsinformatik und die Medizinische Informatik in Bezug auf den jeweils fokussierten Untersuchungsgegenstand voneinander ab (Rohner und Winter 2008). Während die Wirtschaftsinformatik vorrangig die Entwicklung und Nutzung von Informationssystemen in der Unternehmenspraxis zum Untersuchungsgegenstand hat (Österle et al. 2010) und dabei primär betriebswirtschaftlich Fragestellungen adressiert (Scheer 2009), betrachtet die Medizinische Informatik die Entwicklung und Nutzung von Informationssystemen innerhalb des Gesundheitswesens und fokussiert vor allem klinische Fragestellungen des Technikeinsatzes (Rohner und Winter 2008, Winter et al. 2008)[12, 13].

Unabhängig von den jeweils betrachteten Untersuchungsgegenständen, haben sich beide Disziplinen ähnlichen, übergeordneten Forschungsaufträgen verschrieben. So soll zum einen der wissenschaftliche Erkenntnisstand über den Einsatz und die Nutzung von Informationssystemen angereichert werden (Österle et al. 2010, Winter 2013). Auf der anderen Seite sollen innovative Informationssysteme für den Praxiseinsatz konzipiert, entwickelt und umgesetzt werden. Schließlich sollen, ausgehend von einem realwissenschaftlichen Grundverständnis, Best Practices und Handlungsempfehlungen für den Einsatz und das Management von Informationssystemen identifiziert und an die Praktiker weitergegeben werden (Haux et al. 2013, Österle et al.

[12] eHealth gilt als transdisziplinäres Forschungsgebiet der Wirtschaftsinformatik und der Medizinischen Informatik (Rohner und Winter 2008).

[13] Winter (2013) schlägt weiterhin das Heranziehen ethischer Richtlinien als abgrenzende bzw. identitätsstiftende Kriterien vor. So haben die wissenschaftlichen Fachgesellschaften der Medizinischen Informatik (FAMI, GMDS) Leitlinien definiert, die konkrete Erwartungen an die Forschungsaktivitäten stellen. Diese sollen „[...] Gesunde und Kranke sowie die medizinisch Tätigen und Forschenden darin unterstütz[en], Krankheiten vorzubeugen, zu heilen und zu lindern sowie deren Ursachen und Wirkungen besser zu verstehen." (Winter et al. 2008). Analog zu diesem Forschungsauftrag (Erhalt und Erhöhung des Patientenwohls) lässt sich der übergreifende Forschungsauftrag der Wirtschaftsinformatik über die Zielstellung der unternehmerischen Prosperität definieren (Winter 2013).

2010, Winter et al. 2008). Die entsprechenden Forschungsaktivitäten sollen sich dabei vor allem durch Originalität auszeichnen. „*Only, if a research result is at least in part original, it may qualify as scientific"* (Frank 2006, S. 34). Nachfolgend wird aufgezeigt, inwiefern sich die Erkenntnisziele der vorliegenden Arbeit in Bezug auf die dargestellten, interdisziplinären Forschungsaufträge einordnen lassen. Außerdem soll aufgezeigt werden, worin die Originalität der durchgeführten Forschungsaktivitäten gesehen wird.

Anreicherung des wissenschaftlichen Erkenntnisstandes: Die Grundlagenforschung zählt, wie auch in anderen Wissenschaftsdisziplinen, zu den zentralen Aufträgen der Wirtschaftsinformatik und der Medizinischen Informatik (Detel 2007, Winter 2013). Forscher beider Disziplinen sind zu einer (Weiter-)entwicklung von Theorien, Methoden und Werkzeugen aufgerufen, mit denen intersubjektive Erkenntnisse über die Anwendung von Informationssystemen generiert und weiterentwickelt werden können (Österle et al. 2010, Winter 2013). Die Beschreibung und Erklärung der Verbreitung innovativer Informationssysteme nimmt hierbei eine herausragende Rolle ein (Frank 2009). Die Umsetzung einer skalierbaren Austauschplattform besitzt offensichtliches Potenzial, den wissenschaftlichen Erkenntnisstand anzureichern. So können durch den kontinuierlichen Rückkopplungsprozess zwischen Praxis und Forschung fortlaufend empirische Daten und Informationen über die Verbreitung innovativer Technologien erfasst und hypothesenprüfend genutzt werden. Die *Diffusion of Innovation Theory*, die das theoretische Fundament der Plattform darstellt und durch diese validiert und weiterentwickelt werden soll (vgl. Kapitel 2), wird dabei gleichermaßen in der Wirtschaftsinformatik und in der Medizinischen Informatik herangezogen (Cresswell und Sheikh 2013, Greenhalgh et al. 2004, Houy et al. 2016). Abgesehen von diesem allgemeinen Beitrag zur Theorieprüfung und -weiterentwicklung, kann die prototypische Anwendung der Plattform neue Erkenntnisse zur Beschreibung und Erklärung komplexer eHealth-Innovationen generieren. Dabei stehen Krankenhäuser stellvertretend für wissensintensive Expertenorganisationen, deren Besonderheiten als Anwendungs- und Forschungsfeld auch für die Wirtschaftsinformatik von Interesse ist (Österle et al. 2010).

Gestaltung innovativer Informationssysteme: Neben der Entwicklung neuer Theorien ist die Gestaltung innovativer Informationssysteme sowie die dafür notwendige Entwicklung von Konzepten, Modellen und Methoden ein erklärter Auftrag von Wirtschafts- und Medizinischer Informatik (Österle et al. 2010, Winter 2013). Die Konzeption, Entwicklung und Umsetzung einer skalierbaren Austauschplattform lässt sich diesem Auftrag unterordnen. Originalität ergibt sich zum einen aus dem skalierbaren Ansatz der Plattform, da sich vor allem hinsichtlich der technische Umsetzung verschiedene Anforderungen ergeben (siehe Kapitel 2). In diesem Zusammenhang verspricht auch die Zielsetzung einer ressourcenschonenden Umsetzung des Verfahrens einen Erkenntnisgewinn für Wirtschafts- und Medizinische Informatik, da diese im Allgemeinen (Drew 1997) und auch in Bezug auf IT-Benchmarks (Teuteberg et al. 2009) bis dato nicht ausreichend adressiert wurde.

Ableitung von Handlungsempfehlungen: Sowohl die Wirtschaftsinformatik als auch die Medizinische Informatik verstehen sich als Realwissenschaft, die versucht, praktische Handlungsempfehlungen für den Einsatz und das Management innovativer Informationssysteme zu geben (Haux et al. 2004, Österle et al. 2010, Scheer et al. 2005, Winter et al. 2008). Nach Frank (2009) geht dieser Auftrag über die verhaltens- und gestaltungsorientierte Beschreibung, Erklärung und Konstruktion von Informationssystemen hinaus und versucht im Sinne einer „Konstruktion neuer Welten" (Frank 2009, S. 168) gehaltvolle und fundierte Orientierungen für den zukünftigen Einsatz von Informationstechnologien zu geben. Eine besondere Herausforderung stellt hierbei die Kontingenz innovativer Informationstechnologien dar, die nach Frank (2009) nur eingeschränkt theoretisch abgebildet bzw. im Sinne eines konstruktivistischen Ansatzes in Form von Best Practices und Handlungsempfehlungen in die Wirklichkeit zurückgespiegelt werden kann. Vielmehr müssen entscheidungsunterstützende Informationen durch einen fortlaufenden Rückgriff auf die Empirie generiert werden. Die Zielsetzung einer skalierbaren Benchmarkingplattform, die im Sinne des *innovationskatalytischen Prinzips* kontinuierlich handlungsunterstützende Informationen generiert, entspricht dieser Forderung (vgl. Kapitel 1). Abbildung 3 fasst die vorab beschriebene, interdisziplinäre Einordnung der Forschungsaktivitäten dieser Dissertation grafisch zusammen.

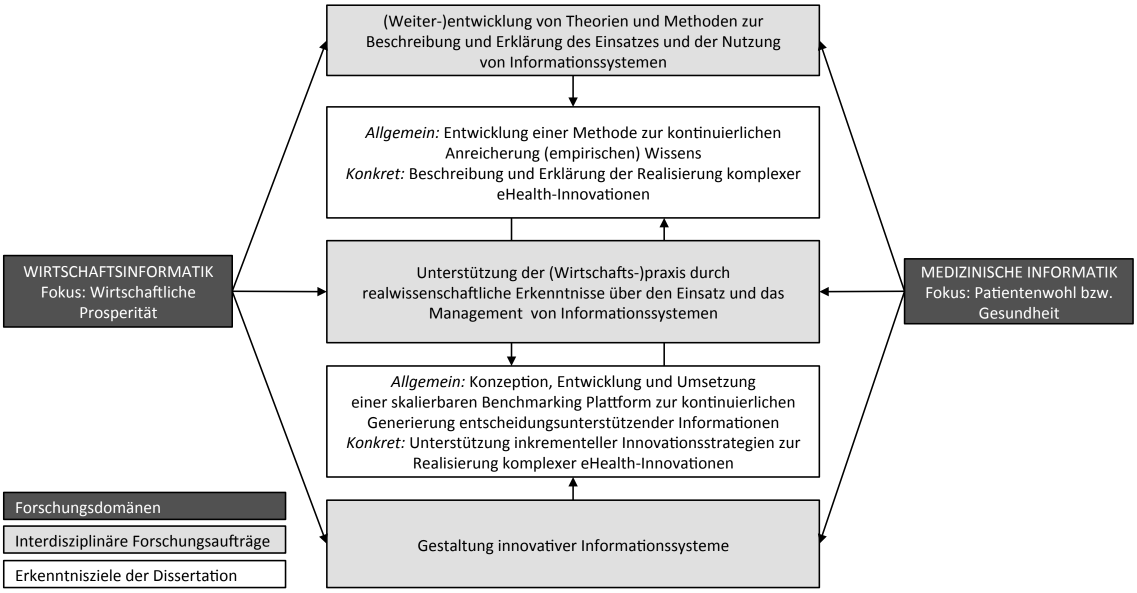

Abbildung 3. Interdisziplinäre Einordnung der Forschungsaktivitäten

4 Methodik

4.1 Rahmenkonzept

In Anlehnung an die beschriebene Zielsetzung und im Hinblick auf deren methodische Umsetzung, lassen sich die Forschungsaktivitäten der vorliegenden Arbeit idealtypisch in das *Information Systems Research Framework* von Hevner et al. (2004) einordnen. Dieses soll nachfolgend näher erläutert werden.

Nach Hevner et al. (2004) ergeben sich die *Relevanz* und *Rigorosität* wissenschaftlicher Forschungsaktivitäten über den fortlaufenden Rückgriff auf die empirische Unternehmenspraxis einerseits und den ständigen Bezug auf den aktuellen, wissenschaftlichen Erkenntnisstand andererseits. Zur Beschreibung dieses wechselseitigen Austauschverhältnisses wird ein Drei-Säulen-Modell vorgeschlagen, in dem die *Forschung* (2. Säule) zwischen der *Praxis* (1. Säule) einerseits und der *Wissensbasis* (3. Säule) andererseits eingebettet ist.

Die Praxis wird über die Determinanten *Menschen*, *Organisationen* und *Technik* definiert. Übertragen auf die prototypische Umsetzung der Plattform lassen sich diese Elemente übersetzen in: IT-Stakeholder, Krankenhäuser und komplexe eHealth-Innovationen (vgl. Kapitel 1). Durch die Interaktion von Menschen, Organisationen und Technik entstehen nach Hevner et al. (2004) konkrete *Probleme, Aufgaben* und *Möglichkeiten*. Auch diese lassen sich in Bezug auf das Anwendungsfeld der Plattform definieren. So sehen sich Krankenhäuser einem zunehmendem Kosten-, Qualitäts- und Servicewettbewerb ausgesetzt, wobei eHealth-Innovationen vielfältige Lösungsmöglichkeiten bieten, diesen Herausforderungen gerecht zu begegnen (Möglichkeiten). Hierdurch ergibt sich der Bedarf, diese digitalen Wettbewerbsoptionen in Form komplexer eHealth-Innovationen umzusetzen (Aufgabe), wobei sich aus den spezifischen Vor- und Rahmenbedingungen der Krankenhäuser (wissensintensive Expertenorganisation, starre Hierarchien, etc., vgl. Kapitel 1), konkrete Anforderungen an die IT-Entscheider ergeben (Problem).

Vor dem Hintergrund dieser *business needs* (Hevner et al. 2004) ist insbesondere die gestaltungsorientierte Forschung dazu aufgerufen, relevante Lösungsansätze zu entwickeln, was in der vorliegenden Arbeit in Form einer skalierbaren Austauschplattform anvisiert wird. Lösungsansätze manifestieren sich nach Hevner et al. (2004) in Form von Artefakten, wobei zwischen *Konstrukten*, *Modellen*, *Methoden* und *Instanziierungen* unterschieden wird. Konstrukte bieten die Sprache, in denen Probleme und Lösungen beschrieben und kommuniziert werden. Modelle nutzen Konstrukte, um einen Ausschnitt aus der Realwelt zu erklären und Zusammenhänge zwischen Problemen und Lösungen aufzeigen. Methoden können somit auch Best Practices bzw. Handlungsempfehlungen zur Lösung von Problemen bieten. „*They provide guidance on how to solve problems, that is, how to search the solution space"* (Hevner et al. 2004, S. 79). Methoden reichen dabei von formellen Algorithmen bis hin zu textlichen Beschreibungen. Durch Instanziierungen werden Konstrukte, Modelle und Methoden in ein *Working System* (Hevner et al. 2004) überführt. *„[Instantiations] demonstrate feasibility, enabling concrete assessment of an artefacts suitability to its intended purpose"* (Hevner et al. 2004, S. 79).

Die Wissensbasis, an der sich die rigorose Entwicklung der Artefakte der Plattform orientieren soll, besteht nach Hevner et al. (2004) aus bereits entwickelten Methoden, Modellen und Theorien, sowie aus validierten empirischen Erkenntnissen über das anvisierte Forschungsfeld. Nachfolgend soll beschrieben werden, welche Artefakte als Lösungsansätze vorgeschlagen werden, welche Forschungsfragen sich daraus ableiten lassen und welche Methoden zur Beantwortung dieser Forschungsfragen genutzt werden sollen.

4.2 Forschungsfragen

Ausgehend von der in Kapitel 2 formulierten Zielsetzung ergibt sich die folgende, übergeordnete Fragestellung:

> FF: Wie kann auf Basis des *innovationskatalytischen Prinzips* eine skalierbare Benchmarkingplattform konzipiert, entwickelt und umgesetzt werden?

Diese übergeordnete Forschungsfrage lässt sich im Hinblick auf die prototypische Umsetzung der Plattform in vier Teilforschungsfragen untergliedern. Dabei soll jede Teilforschungsfrage auf die methodische Umsetzung von vorab spezifizierten Lösungsansätzen (bzw. Artefakten) abzielen. Für die Durchführung von Benchmarkings müssen in einem ersten Schritt geeignete Vergleichsgrößen (Benchmarking-Objekte) definiert und in Form messbarer Key-Performance-Indikatoren (KPI) operationalisiert werden (Jahn et al. 2015, Kütz 2013). Für die anvisierte Austauschplattform soll der Realisierungsgrad komplexer eHealth-Innovationen das zentrale Benchmarking-Objekt darstellen. Wie bereits in Kapitel 1 beschrieben, handelt es sich hierbei um ein *Clusterphänomen* (Rasche 2017), welches sowohl technische, als auch organisatorische Elemente umfasst und zudem evolutionär entsteht (Hübner 2015). Vor diesem Hintergrund müssen die Vergleichsgrößen der Plattform sowohl die Vielschichtigkeit, als auch den graduellen Charakter komplexer eHealth-Innovationen beschreiben. Da eHealth-Anwendungen in den Krankenhäusern vor allem klinische Prozesse unterstützen sollen, müssen die entwickelten Konstrukte zudem einen Prozessbezug aufweisen. Darüber hinaus muss der Realisierungsgrad unabhängig von definierten Einzelfällen erfasst und zwischen verschiedenen Krankenhäusern verglichen werden können (räumliche Skalierbarkeit, vgl. Kapitel 2). Hieraus ergibt sich, dass das Benchmarking-Objekt in Form von quantitativen KPIs operationalisiert werden muss (Ammenwerth et al. 2007). Damit diese aussagekräftig sind, müssen schließlich geeinte Informationsquellen bzw. Befragungsteilnehmer identifiziert werden, durch welche die Vergleichsgrößen erhoben werden können. Im Zusammenhang mit dem vorab beschriebenen methodischen Rahmenkonzept von Hevner et al. (2004) bieten sich *Konstrukte* als Lösungsartefakte zur Beschreibung der Benchmarking-Objekte und ihrer Quantifizierung als KPIs an. Vor diesem Hintergrund lautet die erste Teilforschungsfrage:

> TFF1: Wie kann der Realisierungsgrad komplexer eHealth-Innovationen als Benchmarking-Objekt in geeigneter Form beschrieben werden und durch wen können die entsprechenden KPIs erfasst werden?

Damit die Plattform im Sinne des *innovationskatalytischen Prinzips* den wissenschaftlichen Erkenntnisstand erweitern kann (vgl. Kapitel 2), müssen Ursache- und Wirkungszusammenhänge zwischen den Benchmarking-Objekten (bzw. Konstrukten) theoriebasiert erklärt und empirisch validiert werden. Wie im vorangegangenen Kapitel dargestellt, eignet sich zur Darstellung entsprechender Zusammenhänge die Entwicklung von *Modellen* (vgl. Kapitel 4.1). Die zweite Teilforschungsfrage lautet daher:

> TFF2: Wie kann die Realisierung komplexer eHealth-Innovationen modellhaft erklärt werden?

Ebenfalls im Sinne des *innovationskatalytischen Prinzips* soll das Verfahren vergleichsgruppenspezifisch entscheidungsunterstützende Informationen zur Realisierung komplexer eHealth-Innovationen identifizieren und diese den IT-Stakeholdern der Krankenhäuser zur Verfügung stellen (vgl. Kapitel 2). Als Lösungsansatz können hierfür nach Hevner et al. (2004) *Methoden* entwickelt werden (vgl. Kapitel 4.1). Im Hinblick auf die Entwicklung dieser Methoden ergibt sich die dritte Teilforschungsfrage:

> TFF3: Wie kann eine vergleichsgruppenbezogene Ableitung entscheidungsunterstützender Informationen zur Realisierung komplexer eHealth-Innovationen methodisch umgesetzt werden?

Wie in Kapitel 2 beschrieben, soll das Verfahren skalierbar sein. Hieraus ergeben sich konkrete Anforderungen an die Datenerhebung, -haltung, -analyse und -visualisierung. So sollen zum einen longitudinale Auswertungen ermöglicht werden (bspw. für Panelstudien), was in einem entsprechenden Datenmodell abgebildet werden muss. Konkret sollen identische Teilnehmer und Items aufeinander abgebildet werden können bzw. Veränderungen der Datensätze persistent historisierbar sein. Zudem soll die Datenerhebung und -auswertung möglichst ressourcenschonend gestaltet werden, da eine zeiteffiziente Durchführung positive Kosten-Nutzen-Erwägungen motivieren und somit die Wahrscheinlichkeit zusätzlicher Benchmarking-Teilnahmen erhöhen kann (räumliche Skalierbarkeit). Im Hinblick auf die entsprechende *Instanziierung* der Plattform ergibt sich die vierte Teilforschungsfrage:

> TFF4: Wie kann eine zeitlich, räumlich und inhaltlich skalierbare Benchmarkingplattform informationstechnologisch optimal umgesetzt werden?

4.3 Methodenspektrum

Ausgehend von den Forschungsfragen soll nachfolgend beschrieben werden, mit welchen Methoden die oben beschriebenen Lösungsansätze (Artefakte) konzipiert, entwickelt und umgesetzt wurden. Das methodische Vorgehen erfolgte dabei in einem iterativen Prozess über drei Benchmarking-Runden.

Konstrukte: Der Realisierungsgrad komplexer eHealth-Innovationen (TFF1) wurde über vier Konstrukte beschrieben. Diese definierten zum einen den technischen Reifegrad und zum anderen das IT-Management, die IT-Governance und die IT-Innovationskultur. Die Quantifizierung erfolgte in Anlehnung an Hübner (2015) und Otieno et al. (2008) über Composite Scores. Hierfür wurden die Konstrukte in reliable und valide Messinstrumente übertragen. Die dabei durchgeführten, mehrstufigen Operationalisierungsprozesse orientierten sich an dem von MacKenzie et al. (2004) vorgeschlagenen Rahmenwerk *Construct Measurement and Validation Procedures in MIS and Behavioral Research: Integrating New and Existing Technique*. Die jeweils durchgeführten, mehrstufigen Operationalisierungsprozesse umfassten unter anderem Literaturreviews, Experteninterviews, Skalenbildung, Pretests und Skalenvalidierungen.

Modelle: Die Entwicklung des Erklärungsmodells (TFF2) erfolgte über deduktive und induktive Verfahren. Zum einen wurden in Anlehnung an existierende Modelle und Theorien (insb. die *Diffusion of Innovation Theory*, das *Information System Success Model* sowie *Donabedians Qualitätsmodell*) Zusammenhänge zwischen den Konstrukten modelliert. In induktiven Ansätzen wurde das Modell durch statistische Verfahren (insb. Korrelationen, Unterschiedstests, multiple Regressionsanalysen) auf Basis empirischer Daten validiert.

Methoden: Die Entwicklung von Methoden für die Ableitung entscheidungsunterstützender Informationen (TFF3) basierte auf Literaturreviews, Experteninterviews, statistischen Verfahren und konzeptionellen Methoden.

Instanziierung: Für die technische Umsetzung (TFF4) wurden Anforderungsanalysen und Systemspezifikationen durchgeführt. Das Verfahren wurde nach jeder Runde evaluiert, wobei von den Teilnehmern unter anderem die Nützlichkeit der zurückgespiegelten KPIs und deren Visualisierung bewertet wurde. Die Evaluation basierte auf telefonischen Interviews und Evaluationsfragebögen.

4.4 Gang der Forschung

In Anlehnung an das *Information Systems Research Framework* von Hevner et al. (2004) (vgl. Kapitel 4.1) wird in Abbildung 4 der Gang der Forschungsarbeiten dargestellt. Die Abbildung verortet die Zielsetzungen der Arbeit und stellt dar, wie diese miteinander zusammenhängen. Zudem wird in der Grafik gezeigt, wie die vier Artefakte als konstituierende Lösungsansätze der Benchmarkingplattform im Verlauf der drei Runden kontinuierlich (weiter-) entwickelt und umgesetzt wurden. Schließlich zeigt die Abbildung, wie durch das Verfahren am Beispiel komplexer eHealth-Innovationen praktische und wissenschaftliche Implikationen generiert werden konnten. Die Forschungsbeiträge der vorliegenden Dissertation werden in der Abbildung neben den Artefakten dargestellt.

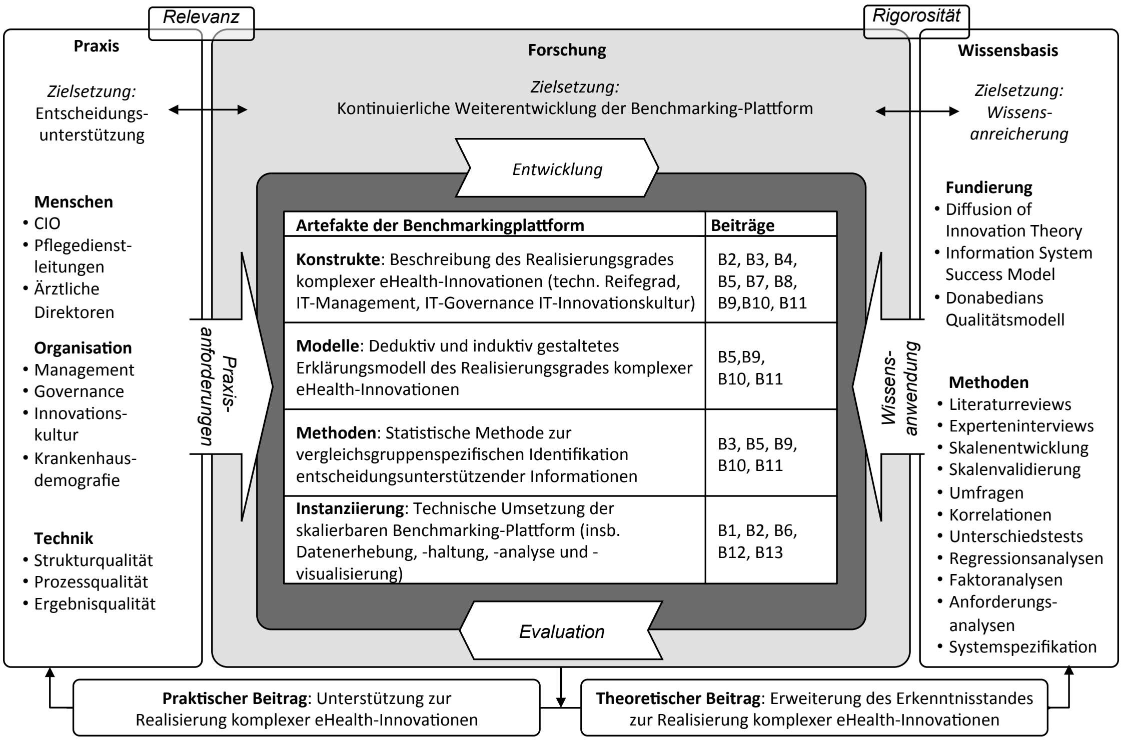

Abbildung 4. Gang der Forschung

5 Ergebnisse

Tabelle 1 gibt einen Überblick der eingebrachten Einzelbeiträge B1 bis B13 unter Angabe der Publikationsorgane und bibliographischen Informationen. Ebenfalls in der Tabelle aufgelistet sind die Bewertungen der Publikationsorgane nach dem Ranking des Jourqual 3 des VHB, den Orientierungslisten der WKWI sowie die Impact Faktoren und die Annahmequoten der Journals und Konferenzen. Die Beiträge B1 bis B10 waren zum Zeitpunkt der Abgabe dieser Dissertationsschrift veröffentlicht. Die Beiträge B11 bis B13 wurden angenommen und waren zum Zeitpunkt der Abgabe in Veröffentlichung.

Tabelle 1. Überblick über die Einzelbeiträge

Nr.	Publikations-organ	Annahmequote Ranking	Bibliographische Informationen
B1	Methods of Information in Medicine	WKWI: - VHB JQ3: - IF: 2,248 AQ: 25%-30%	**Liebe, J.-D.** und Hübner, U. (2013) *Developing and Trialling an Independent, Scalable and Repeatable IT Benchmarking Procedure for Healthcare Organisations*. Methods of Information in Medicine, 52(4), S. 360-369.
B2	Studies in Health Technology and Informatics	WKWI: - VHB JQ3: - IF: - AQ: 52%	Thye, J., Straede, M.-C., **Liebe, J.-D.** und Hübner, U. (2014) *IT Benchmarking of Clinical Workflows: Concept, Implementation, and Evaluation*, in: Hörbst, A., Hayn, D., Schreier, G., Ammenwerth, E. (Hrsg.): Tagungsband der eHealth2014 – Health Informatics Meets eHealth - Outcomes Research: The Benefit of Health-IT (eHealth 2014), Studies in Health Technology and Informatics, Wien, Amsterdam, S. 116-124.
B3	Methods of Information in Medicine	WKWI: - VHB JQ3: - IF: 2,248 AQ: 25%-30%	**Liebe, J.-D.**, Hübner, U., Straede, M. und Thye, J. (2015) *Developing a Workflow Composite Score to Measure Clinical Information Logistics*. Methods of Information in Medicine, 54(5), S. 424-433.
B4	Lecture Notes in Informatics (LNI)	WKWI: - VHB JQ3: C IF: - AQ: -	Kücherer, C., **Liebe, J. D.**, Schaaf, M., Thye, J., Paech, B., Winter, A. und Jahn, F. (2016) *The Status Quo of Information Management in Hospitals - Results of an Online Survey*, in: Mayr, H.,C., Pinzger, M. (Hrsg.): 46. Jahrestagung der Gesellschaft für Informatik, Informatik von Menschen für Menschen (Informatik 2016), LNI, P-259, Klagenfurt, Bonn, S. 685-698.
B5	BMC Medical Informatics and Decision Making	WKWI: - VHB JQ3: - IF: 2,042 AQ: 62%	**Liebe, J.-D.**, Hüsers, J. und Hübner, U. (2016) *Investigating the Roots of Successful IT Adoption Processes - an Empirical Study Exploring the Shared Awareness-knowledge of Directors of Nursing and Chief Information Officers*. BMC medical informatics and decision making, 16(1), S.1-10.
B6	Journal of Biomedical Engineering and Informatics	WKWI: - VHB JQ3: - IF: - AQ: 46%	Thye, J., Hübner, U., Straede, M.-C. und **Liebe, J.-D.** (2016) *Development and Evaluation of a Three-Dimensional Multi-level Model for Visualising the Workflow Composite Score in a Health IT Benchmark*. Journal of Biomedical Engineering and Informatics, 2(2), S. 83-98.
B7	International Journal of Medical Informatics	WKWI: - VHB JQ3: - IF: 2,362 AQ: 19%	Esdar, M., Hübner, U., **Liebe, J.-D.**, Hüsers, J. und Thye, J. (2017) *Understanding Latent Structures of Clinical Information Logistics: A bottom-up Approach for Model Building and Validating the Workflow Composite Score. International journal of medical informatics*, 97, S. 210-220.
B8	Studies in Health Technology and Informatics	WKWI: - VHB JQ3: - IF: - AQ: 62%	Esdar, M., **Liebe, J.-D.**, Weiß, J. und Hübner, U. (2017) *Exploring Innovation Capabilities of Hospital CIOs: An Empirical Assessment*, in: Randell, R., Cornet, R., McCowan, C., Peek, N., Scott, P.J. (Hrsg.): Informatics for Health: Connected Citizen - Led Wellness and Population Health (Informatics for Health 2017), Studies in Health Technology and Informatics, Manchester, Amsterdam, S. 383-387.
B9	Journal of Medical Systems	WKWI: - VHB JQ3: - IF: 2,213 AQ: 37,5%	Hüsers, J., Hübner, U., Esdar, M., Ammenwerth, E., Hackl, W. O., Naumann, L. und **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), S. 1-16.
B10	Wirtschafts-informatik (WI)	VHB JQ3: C WKWI: A IF: - AQ: 32,3%	**Liebe, J.-D.**, Thomas, O., Jahn, F., Kücherer, C., Esdar, M., Weiß, J.-P., Hüsers, J. und Hübner, U. (2017) *Zwischen Schattendasein, Governance und Entrepreneurship - Eine empirische Bestandsaufnahme zum Professionalisierungsgrad des IT Managements in deutschen Krankenhäusern*, in: Leimeister, J.M., Brenner, W. (Hrsg.): Tagungsband der 13. internationalen Konferenz der Wirtschaftsinformatik (WI 2017), AISeL, St. Gallen, S. 559-573.
B11	Lecture Notes in Informatics (LNI)	WKWI: - VHB JQ3: C IF: - AQ: -	Weiß J.-P., Rauch, J., Hüsers, J.**, Liebe, J.-D.**, Teuteberg, F., und Hübner, U. (2017) *Entwicklung eines Datenmodells für ein umfassendes Forschungsdatenmanagement zur flexiblen Analyse longitudinaler Daten*, in: Eibl, M., Gaedke M., Winter C., (Hrsg.): 47. Jahrestagung der Gesellschaft für Informatik, Digitale Kulturen (Informatik 2017), LNI, in Veröffentlichung, Chemnitz, Bonn, S. 1-15.
B12	Studies in Health Technology and Informatics	VHB JQ3: - WKWI: - IF: - AQ: 50%-70%	**Liebe, J.-D.**, Esdar, M., Thye, J., und Hübner, U. (2017) *Antecedents of CIOs' Innovation Capability in Hospitals: Results of an Empirical Study,* in: Rörig, R., Timmer A. (Hrsg.): 62. GMDS-Jahrestagung, Mit Visionen Brücken bauen (GMDS 2017), Studies in Health Technology and Informatics, in Veröffentlichung, Oldenburg, Amsterdam, S. 1-5.
B13	Studies in Health Technology and Informatics	VHB JQ3: - WKWI: - IF: - AQ: 50%-70%	Weiß J.-P., Hübner, U., Rauch, J., Teuteberg, F., Esdar, M., **Liebe J.-D**. (2017) *Implementing a Data Management Platform for Longitudinal Health Research*, in: Rörig, R., Timmer A. (Hrsg.): 62. GMDS-Jahrestagung, Mit Visionen Brücken bauen (GMDS 2017), Studies in Health Technology and Informatics, in Veröffentlichung, Oldenburg, Amsterdam, S. 1-5.

Legende:

VHB JQ3 = Verband der Hochschullehrer für Betriebswirtschaft e. V. Journal Quality Index 3.

WKWI = Wissenschaftliche Kommission Wirtschaftsinformatik im Verband der Hochschullehrer für Betriebswirtschaft und Fachbereich Wirtschaftsinformatik der Gesellschaft für Informatik (2008) WI-Orientierungslisten. Wirtschaftsinformatik, 50 (2), S. 155–163.

IF = Impact Faktor des Journal Citation Report von Thomson Reuters.

AQ = Annahmequote nach Angaben der Journal-Homepage, der Editoren und der wissenschaftlichen Konferenzleitung.

5.1 Arbeiten

5.2 Konstrukte

Zur Beschreibung des *Realisierungsgrades komplexer eHealth-Innovationen* als Benchmarking-Objekte bzw. KPIs wurden vier Konstrukte entwickelt (technischer Reifegrad, IT-Management, IT-Governance, IT-Innovationskultur). Die Ergebnisse sollen nachfolgend beschrieben werden, wobei sich die Darstellung an dem genutzten Rahmenwerk von MacKenzie et al. (2011) orientiert (vgl. Kapitel 4). In einem ersten Schritt wird aufgezeigt, wie das jeweilige Konstrukt definiert wurde. Hierauf aufbauend wird beschrieben, welche Items bzw. Skalensets zur Messung des Konstrukts gebildet wurden. Weiterhin wird angegeben, wie und durch welche IT-Stakeholder die jeweiligen Konstrukte erfasst wurden. Schließlich werden Ergebnisse der Skalenvalidierung präsentiert. Im Verlauf der Darstellung soll auch auf die inhaltliche Skalierung des Verfahrens eingegangen werden, die eine zentrale Anforderung an das Verfahren darstellt (vgl. Kapitel 2). Konkret soll hierbei gezeigt werden, wie die Konstrukte bzw. ihre Operationalisierung im Verlauf der drei Benchmarking-Runden iterativ, relevant und rigoros weiterentwickelt werden konnten.

5.2.1 Technik

Definitionen des technischen Reifegrades: Der technische Reifegrad komplexer eHealth-Innovationen wurde in Anlehnung an das Qualitätsmodell von Donabedian (1988) über die Struktur-, Prozess- und Ergebnisqualität des KIS definiert (Donabedian 1988).[14] Die *Strukturqualität* wurde als die erste Reifegradstufe festgelegt und in Anlehnung an Ammenwerth et al. (2008) als das Vorhandensein technischer KIS-Attribute beschrieben[15]. Unter technischen KIS-Attributen wurden insbesondere Hard- und Software-Komponenten, Peripherie, Architektur und Netzwerke verstanden. Aufbauend auf der Strukturqualität wurde als zweite Reifegradstufe die *Prozessqualität* in Anlehnung an das informationslogistische Prinzip von Augustin (1990) definiert. Die Prozessqualität beschreibt, inwiefern das KIS die technischen Voraussetzungen erfüllt, den klinischen Anwendern die richtigen Informationen, zur richtigen Zeit, am richtigen Ort in der richtigen Qualität elektronisch zur Verfügung zu stellen[16]. Zur näheren Spezifikation der so bezeichneten *klinischen Informationslogistik* (B3, B7) wurden vier Deskriptoren definiert: (1.) *Funktion*, definiert als die technische Verfügbarkeit prozessrelevanter IT-Funktionen, (2.) *Daten und Informationen*, definiert als die technische Verfügbarkeit prozessrelevanter elektronischer Patientendaten, (3.) *Integration*, definiert als die Tiefe der technischen Integration (im Sinne interoperabler Systeme) und (4.) *Distribuierbarkeit*, definiert als das technische Potenzial, IT-Funktionen bzw. elektronische Patientendaten mobil im Behandlungsgeschehen zur Verfügung zu stellen. Zur Herstellung eines Prozessbezuges wurden die Deskriptoren durch einen zweiachsigen Ordnungsrahmen vier klinischen Prozessen zugeordnet (B3). Im Sinne der räumlichen

[14] Die Auswahl des Modells orientierte sich u.a. an Ammenwerth et al. (2008), die das Donabedian-Modell zur Beschreibung der KIS-Qualität vorschlagen. Zudem basierte die Auswahl auf der Annahme, dass das Donabedian-Modell den Benchmarking-Stakeholdern eine nachvollziehbare Beschreibungssystematik bietet, da es unter Praktikern im Gesundheitswesen anerkannt und verbreitet ist.

[15] Gegenüber der Definition von Winter et al. (2010), die KIS als soziotechnische Systeme definieren, wurde in dem vorgeschlagenen Konstrukt bewusst ausschließlich die technische Ebene fokussiert, da nur so eine distinkte Abgrenzung zwischen den vier Konstrukten erreicht werden konnte.

[16] Die genutzte Definition der Prozessqualität wurde vor dem Hintergrund des verhaltensorientierten bzw. fragebogengestützten Ansatzes des Verfahrens gewählt. Es soll an dieser Stelle nicht unerwähnt bleiben, dass Prozessqualität im Bereich des IT-Managements und der IT-Governance auch anders beschrieben und erfasst wird. Insbesondere in gestaltungsorientierten Ansätzen werden zumeist objektive, elektronische Daten zur Quantifizierung der Prozessqualität erfasst (Durchlaufzeiten, Down-Times, etc.) (Hevner et al. 2004).

Skalierbarkeit sollten die Prozesse möglichst vergleichbar sein (vgl. Kapitel 2). Ausgehend von sieben Experteninterviews wurden daher die Visite, die OP-Vorbereitung, die OP-Nachbereitung und die Entlassung ausgewählt (B3, B6, B7). Im Verlauf der inhaltlichen Skalierung des Verfahrens wurde die Auswahl der Prozesse in der dritten Benchmarking-Runde durch Hinzunahme des Aufnahmeprozesses erweitert. Während die Prozessqualität das technische Potenzial zur Prozessunterstützung beschreibt, definiert die *Ergebnisqualität* als dritte Reifegradstufe, ob dieses Potenzial auch tatsächlich von den klinischen Anwendern wahrgenommen und anerkannt wird. Die Unterscheidung zwischen technischem und wahrgenommenem Potenzial war ebenfalls Ergebnis der inhaltlichen Skalierung des Verfahrens. So konnte auf Basis empirischer Befunde nachgewiesen werden, dass ein Informationsgradient zwischen CIOs und klinischen Anwendern besteht (B5)[17]. Darüber hinaus wurde mit der Unterscheidung der Tatsache Rechnung getragen, dass letztlich nur die klinischen Anwender einschätzen können, ob das KIS nützlich bzw. innovativ ist: *„Ultimately, it is the clinicians or more broadly the users who have the final say on whether eHealth is really helpful in performing their tasks and thus is innovative*“ (Hübner 2015, S. 322).

Wie auch die Prozessqualität wurde die Ergebnisqualität durch Sub-Dimensionen näher spezifiziert. Hierfür wurde das *Information System Success Model* von Delone und MacLean (2003) als konzeptionelles Rahmenwerk genutzt[18]. In Anlehnung an das Modell wurden fünf Dimensionen gebildet: (1.) *wahrgenommene Systemqualität,* definiert als die subjektiv wahrgenommene Verfügbarkeit von IT-Funktionen zur Unterstützung der klinischen Arbeitsabläufe, (2.) *wahrgenommene Informationsqualität*, definiert als die subjektiv wahrgenommene Verfügbarkeit elektronischer Patienteninformationen in den Prozessen, (3.) *wahrgenommene Partizipationsqualität,* definiert als die wahrgenommene Möglichkeit zur anwenderseitigen Mitgestaltung komplexer eHealth-Innovationen, (4.) *Zufriedenheit*, definiert als die empfundene Zufriedenheit mit der Prozessunterstützung und (5.) *Net Benefit*, definiert als das wahrgenommene KIS-Potenzial, die grundsätzliche Performance des Krankenhauses in den Bereichen Patientenversorgung, Management sowie Forschung und Entwicklung, zu unterstützen (B9).

Operationalisierung des technischen Reifegrades: Zur Messung der *Strukturqualität* wurden insgesamt 92 Items entwickelt, wobei 37 Items die Umsetzungsgrade administrativer und klinischer IT-Funktionen erfassten (z.B. elektronische Arztbriefschreibung, Befund-Anforderung und -Rückmeldung, Alarmfunktionen)[19]. Die Auswahl der abgefragten Funktionen wurde im Verlauf der drei Benchmarking-Runden mehrfach angepasst. Während der Fragebogen in der ersten Benchmarking-Runde bspw. noch den Umsetzungsgrad des elektronischen Archivs erfasste, wurde die entsprechende Frage in der zweiten Runde herausgenommen[20]. Auf der anderen Seite wurden Items zur Abfrage neuer Funktionen hinzugefügt (bspw. CIRS) (B9). Neben den IT-Funktionen wurden Items zur Erfassung der technischen Verfügbarkeit elektronischer

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[17] Der Informationsgradient wurde gemessen, indem CIOs und PDL innerhalb einer Einrichtung deckungsgleiche Fragen zur Umsetzung von IT-Funktionen gestellt wurden. Statistische Unterschiedstests ergaben, dass die PDL die Umsetzung von IT Funktionen signifikant geringer einschätzten als die CIOs (mit Ausnahme besonders pflegerelevanten Funktionen).

[18] Das *Information System Success Model* bietet eine Taxonomie zur anwenderseitigen Evaluation von Informationssystemen. Das Modell hat sich auch im Gesundheitswesen etabliert und wird vor allem in Krankenhäusern genutzt, um die Leistungsfähigkeit des KIS aus der klinischen Perspektive zu erfassen (Van Der Meijden et al. 2003, Otieno et al. 2007, Booth et al. 2012).

[19] Die Umsetzung wurde über Ordinalskalen gemessen: 1 = „Nicht umgesetzt“, 2 = „Noch nicht umgesetzt, allerdings ist die Umsetzung geplant“, 3 = „Umgesetzt in mind. einer Einheit“ und 4 = „Umgesetzt in allen Einheiten“. Für die Umsetzung von Schnittstellenfunktionen wurde lediglich zwischen drei Abstufungsgraden unterschieden 1 = „Nicht umgesetzt“, 2 = „Noch nicht umgesetzt, allerdings ist die Umsetzung geplant“ und 3 = „Umgesetzt in allen Einheiten“.

[20] Die Entscheidung zur Herausnahme der funktionsbezogenen Items erfolgte auf Basis der Umsetzungsgrade in der Gesamtstichprobe. IT-Funktionen, die bereits in den meisten Krankenhäusern vollständig umgesetzt waren, wurden entfernt. Dieses Vorgehen erfolgte auch im Sinne der Fragebogeneffizienz.

Patientendaten gebildet (41 Items, bspw. elektronische Kurven, Vitalparameter, Medikation). Die Items wurden dabei so entwickelt, dass die Datenverfügbarkeit im Kontext der klinischen Prozesse erfasst werden konnte (bspw. „Welche Patientendaten werden am point of care / Patientenbett [elektronisch] zur Verfügung gestellt“). Ebenfalls wurden Items zur Erhebung stationärer und mobiler Endgeräte entwickelt (9 Items, bspw. Bedside-Terminals, Notebooks, Tablets). Weitere Fragen bezogen sich auf die EPA-Umsetzung, auf die Homogenität bzw. Heterogenität der KIS-Architektur und auf die Nutzung von Workflowmanagementsystemen (B3). Da die Prozessqualität auf der Strukturqualität aufbaut, wurden für ihre Erfassung keine zusätzlichen Items gebildet, sondern die oben beschriebenen verrechnet (s.u.). Zur Erhebung der Ergebnisqualität wurde ein zweiter Fragebogen erstellt, der ebenfalls im Verlauf der drei Benchmarking-Runden angepasst bzw. weiterentwickelt wurde (inhaltlich Skalierung). Da die Ergebnisqualität den technischen Reifegrad spiegelbildlich aus Sicht der Anwender erfassen sollte, orientierte sich die Fragebogenentwicklung so weit wie möglich an den oben beschriebenen Items. So bezogen sich bspw. die Fragen zur Operationalisierung der wahrgenommen System- und Informationsqualität auf die gleichen IT-Funktionen und Patientendaten, auf die sich auch die Operationalisierung der Struktur- und Prozessqualität bezog (B9). Auf der anderen Seite wurde die *Zufriedenheit* in Bezug auf die klinischen Prozesse erfasst (z.B. „Wie zufrieden sind Sie mit der in Ihrer Einrichtung genutzten Software zur Unterstützung der [Visite]“).

Erhebung des technischen Reifegrades: Da es sich bei *Struktur-* und *Prozessqualität* um technische Fragestellungen handelt, wurden beide Konstrukte durch die CIOs erfasst (B3, B7). Zur Erhebung der *Ergebnisqualität* wurden die Pflegedienstleitungen (PDL) befragt. Die Auswahl der PDL als Benchmarking-Stakeholder folgte verschiedenen Annahmen: Zum einen repräsentieren PDL die Pflegekräfte und somit die größte Anwendergruppe des KIS (Otieno et al. 2007, Rojas und Seckman 2014). Weiterhin haben PDL bzw. Pflegekräfte besonders umfassende Kenntnisse über das KIS, da sie im Verlauf ihres Arbeitsalltages in vielfältiger Weise mit diesem interagieren (Miller und Sim 2004, Musen und van Bemmel 1997)(B5)[21]. Während PDL somit zum einen gut über das KIS Auskunft geben können, können sie zum anderen auch als Multiplikatoren der Benchmarking-Ergebnisse fungieren. So gelten gerade Kliniker auf oberen Hierarchieebenen als *Agents that informate the clan* (Kohli und Kettinger 2004). Schließlich spielen PDL im Besonderen und Kliniker im Allgemeinen bei der Entwicklung komplexer eHealth-Innovationen eine aktive Rolle, wie in B5 nachgewiesen wurde. Für eine noch umfassendere Beschreibung der klinischen Perspektive wurden in der dritten Benchmarking-Runde neben den CIOs und PDL zusätzlich auch die ärztlichen Direktoren als Benchmarking-Stakeholder in das Verfahren aufgenommen (inhaltliche Skalierbarkeit).

Quantifizierung des technischen Reifegrades: Wie in Kapitel 4 beschrieben, sollten die Daten zur Beschreibung der Konstrukte durch Composite Scores quantifiziert werden. Bezogen auf den technischen Reifegrad konzentrierten sich die entsprechenden Arbeiten innerhalb der vorliegenden Dissertation auf die Quantifizierung der Prozessqualität (B3, B7). Als Berechnungsgrundlage für den hierbei entwickelten *Workflow Composite Scores* (WCS) wurde eine 16-Felder Matrix erstellt, in welcher die vier Deskriptoren den vier Prozessen (s.o.) zugeordnet wurden. Basierend auf den Angaben der CIOs quantifizierte der WCS somit, (1.) inwiefern bspw. innerhalb der Visite die benötigten Funktionen (Deskriptor: Funktionen) und (2.) die benötigten Patientendaten elektronisch zur Verfügung stehen (Deskriptor: Daten und Informationen), (3.) ob die Verfügbarkeit eher stationär oder mobil ausgestaltet ist (Deskriptor: Distribution) und ob (4.) eine integrierte, interoperable Systemarchitektur die Verfügbarkeit unterstützt

[21] Pflegekräfte müssen fortwährend die Pflegeplanung ihrer Patienten berücksichtigen und dabei mögliche *Adverse Events* antizipieren und notwendige Behandlungen planen. Darüber hinaus müssen sie kontinuierlich über den Gesundheitszustand der Patienten informiert sein. Hinzu kommt, dass sie sowohl ihre eigenen Interventionen, oftmals aber auch die der Ärzte, dokumentieren müssen. Schließlich haben Pflegekräfte einen besonders hohen Bedarf an einem mobilen Zugang zu den Informationen, da sie, im Gegensatz zu anderen *Knowledge-Workern*, nicht über einen Büroarbeitsplatz verfügen (Musen und van Bemmel 1997, Miller und Sim 2004).

(Deskriptor: Integration). Ausgehend von einer Gleichverteilung ergab sich für den WCS eine Punkteskala von 1 bis 40 Punkten, sodass in jedem der 16 Prozess-Deskriptorfelder (Sub Scores) maximal 2,5 Punkte erreicht werden konnten. Abbildung 5 verdeutlicht die Berechnungssystematik (B3, B7). Die inhaltliche Validität konnte durch vorab durchgeführte Experteninterviews und Literaturreviews bestätigt werden (B3). Die Reliabilität des Gesamtscores war zufriedenstellend (r_{sb} = 0,886). Gleiches galt für den Deskriptor Funktion (r_{sb} = 0,885) und für den Deskriptor Daten und Informationen (r_{sb} = 0,977). Für die Deskriptoren Integration und Distribution ergaben sich hingegen niedrige Koeffizienten (r_{sb} = 0.359 bzw. r_{sb} = 0,127). Diese Ergebnisse wurden zum Anlass genommen, die Operationalisierung von Integration und Distribution im Sinne der Rigorosität des Benchmarking-Verfahrens in der dritten Runde anzupassen. So wurde Integration in der dritten Runde über 15 anstelle von 9 Items erfasst. Durch die zusätzlich aufgenommenen Items wurde bspw. erfasst, ob das KIS einen Master Patient Index (MPI) zur eindeutigen Identifizierung von Patienten generieren kann. Im Hinblick auf den Deskriptor Distribution wurde die Skalierung der Items angepasst. Während das Vorhandensein von Endgeräten vorher über nominale Ausprägungen erhoben wurde („vorhanden“ vs. „nicht vorhanden“), konnten die Teilnehmer in der dritten Benchmarking-Runde angeben, in wie vielen der Stationen die entsprechenden Endgeräte zur Verfügung stehen (auf einer Skala von 1% bis 100%). Weiterhin wurde die Gewichtung des WCS auf Basis faktoranalytischer Verfahren angepasst, sodass beispielsweise die Umsetzung der EPA ausschließlich dem Deskriptor Integration (und nicht allen Deskriptoren) zugeordnet wurde (B7).

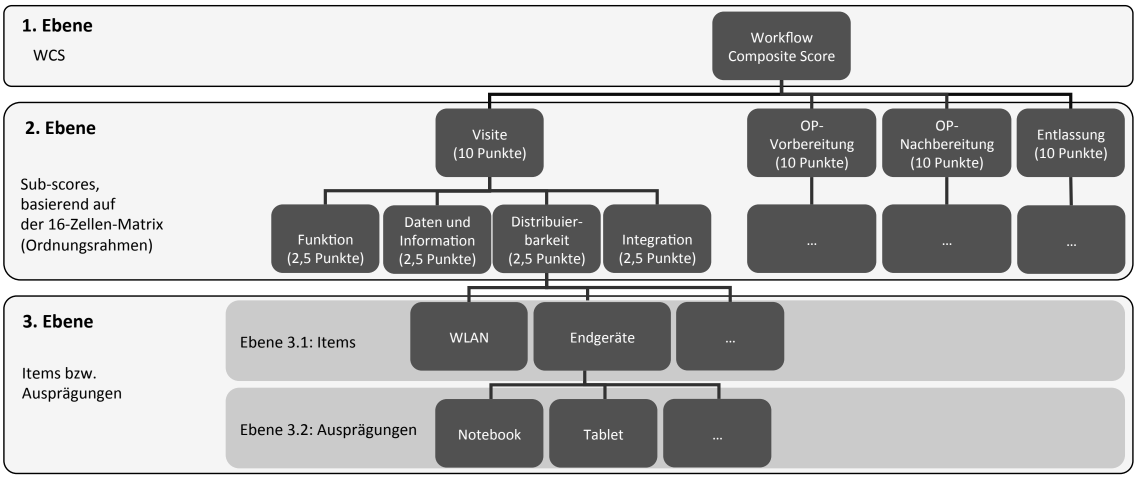

Abbildung 5. Berechnungssystematik des Workflow Composite Scores

5.2.2 Management

Definition des IT-Managements: Als Beschreibungsgröße des IT-Managements wurde der *Professionalisierungsgrad des IT-Managements* vorgeschlagen (B4, B10). Die Definition des Konstrukts orientierte sich insbesondere an Schlegel (2010) und Haux et al. (2013) und wurde durch Experteninterviews inhaltlich validiert. Der Professionalisierungsgrad wurde durch zwei Dimensionen näher spezifiziert. Dies waren (1.) die *quantitative Dimension,* definiert als der Umfang aller durchgeführten Managementhandlungen und (2.) die *qualitative Dimension,* definiert als der Formalisierungsgrad, in dem diese Aktivitäten durchgeführt werden. Beide Dimensionen werden in B10 näher beschrieben.

Operationalisierung des IT-Managements: Die quantitative Dimension des Professionalisierungsgrades wurde in Anlehnung an Haux et al. (2013) über die Anzahl der durchgeführten IT-Managementaktivitäten operationalisiert. Insgesamt 17 Aktivitäten wurden in dem Fragebogen zur Auswahl gestellt, wobei sich diese auf fünf *strategische Aktivitäten* (bspw. Strategische Steuerung in Form der Priorisierung und Initiierung von Projekten), sechs *taktische Aktivitäten* (bspw. IT-Projektmanagement, insb. Projektplanung, -begleitung und -abschluss) und sechs *operative Aktivitäten* (bspw. Betrieb des Help- und Servicedesks) verteilten. Zur Erfassung der qualitativen Dimension wurde in Bezug auf die 17 Managementaktivitäten abgefragt, inwiefern diese formalisiert nach eigens entwickelten bzw. industriellen IT-Governancerahmenwerken durchgeführt werden (B4, B10). Im Sinne der inhaltlichen Skalierung des Verfahrens wurden die CIOs zudem in einer offenen Fragestellung gefragt: „Was ist das für Sie bedeutsamste IT Ziel Ihrer Einrichtung in den nächsten Jahren?" (B4). Basierend auf den entsprechenden Antworten konnte die Operationalisierung des IT-Managements für die dritte Runde um eine standardisierte und somit vergleichbare Frage nach den IT-Zielen angereichert werden.

Erhebung und Quantifizierung des IT-Managements: Der Professionalisierungsgrad wurde durch die CIOs abgefragt, da diese zentral für alle Aktivitäten des strategischen, taktischen und operativen Managements zuständig sind (Haux et al. 2013). Zur Quantifizierung des Professionalisierungsgrades wurde ein gewichteter Summenscore gebildet, indem pro durchgeführte IT-Managementaktivität ein Punkt und pro formalisiert durchgeführter IT-Managementaktivität 1,5 Punkte vergeben wurden. Die moderierende Gewichtung folgte der Annahme, dass formalisiert durchgeführte Managementaktivitäten im Hinblick auf den Professionalisierungsgrad nicht zwangsläufig doppelt so hoch gewertet werden können, wie ad-hoc durchgeführten Aktivitäten, da die Aktivität an sich der wesentliche Aspekt ist. Der gewichtete Summenscore wurde skaliert, sodass der Professionalisierungsgrad des IT-Managements in einem Wertebereich von 0 bis 100 Punkten lag (B10). Zur inhaltlichen Validierung des Scores wurden im Rahmen der Skalenbildung Literaturreviews und Experteninterviews durchgeführt. Die deskriptiven Maße deuten auf eine annähernde Normalverteilung des Scores hin, was als validierendes Ergebnis gedeutet wurde (B10).

5.2.3 Governance

Definition der IT-Governance: Das Konstrukt IT-Governance wurde ebenfalls auf Basis von Literaturanalysen und Experteninterviews definiert (B4, B10). Demnach werden durch die IT-Governance grundsätzlich die Rahmenbedingungen für ein zielorientiertes Management der krankenhausinternen IT-Ressourcen geschaffen (Thatcher 2013). Gegenüber dem IT-Management bezieht sich IT-Governance somit nicht auf die Durchführung IT-bezogener Entscheidungen, sondern auf die Schaffung der hierfür notwendigen Befugnisse und Verantwortlichkeiten (Weill 2004). Vor dem Hintergrund krankenhausspezifischer Vor- und Rahmenbedingungen (B10) und im Hinblick auf den Professionalisierungsgrad des IT-Managements wurde die Ausprägung der IT-Governance über drei Dimensionen spezifiziert: (1.) *hierarchische Positionierung*, definiert als die Stellung des CIOs, bzw. die Einbindung der IT-Abteilung (bspw. direkt der Krankenhausleitung untergeordnet), (2.) *strategisches IT-Alignment*, definiert als die wechselseitige Abstimmung von Strategien, Architekturen, Prozessen und Leistungen zwischen dem IT-Management und den (klinischen) Fachabteilungen und (3.) *IT-Budgetverantwortung,* definiert als die ausgewiesene IT-Budgetverantwortung des CIOs bzw. der IT-Abteilung (B4, B10).

Operationalisierung der IT-Governance: In Orientierung an Leidner et al. (2010) und Smith et al. (2013) wurde die Ausprägung der IT-Governance sowohl über organisatorische Eigenschaften, als auch über individuelle Ausprägungen des CIOs, operationalisiert. Die hierarchische Positionierung wurde entsprechend über zwei Merkmale erfasst (CIO ist Mitglied der KHL und die IT-Abteilung fungiert als Stabsstelle). Das strategische IT-Alignment wurde ebenfalls über zwei Merkmale operationalisiert (Intensität der strategischen Kommunikation zwischen CIO und KHL und Vorhandensein einer, mit der Krankenhausstrategie korrespondierenden IT- Strategie). IT-Budgetverantwortung wurde darüber operationalisiert, ob der CIO bzw. die IT- Abteilung über ein ausgewiesenes IT-Budget verfügen (B4, B10).

Erhebung und Quantifizierung der IT-Governance: Die Ausprägung der IT-Governance wurde durch die CIOs abgefragt. Zur Quantifizierung der IT-Governance wurde im Rahmen der vorliegenden Arbeit kein Score gebildet (B4, B10).

5.2.4 Innovationskultur

Definition der Innovationskultur: Basierend auf Literaturanalysen und Experteninterviews wurde die Innovationskultur definiert als die wahrgenommene Fähigkeit des CIOs, eHealth-Innovationen zu initialisieren, zu implementieren und zu institutionalisieren (B8, B10, B12). Zur Spezifizierung der Innovationskultur wurden drei Sub-Dimensionen gebildet: (1.) *Innovationsklima,* definiert als eine Arbeitsumgebung, welche die Schaffung und Implementierung innovativer eHealth-Lösung fördert und auf gemeinsamen Vorstellungen und Werten bzgl. des Einsatzes und der Nutzung von eHealth-Innovationen basiert, (2.) *Intrapreneurship-Persönlichkeit*, definiert als proaktives, risikoaffines Verhalten des CIOs und der Bereitschaft, mangelnde Entscheidungsbefugnisse durch unternehmerisches Denken und Handeln auszugleichen, (3.) *Offenheit gegenüber Nutzern*, definiert als eine ausgeprägte Orientierung an den Bedürfnissen der klinischen Anwender und der Bereitschaft mit diesen neue Lösungen in Form von eHealth-Innovationen umzusetzen (B8, B10, B12)[22].

Operationalisierung der Innovationskultur: Zur Messung der Innovationskultur wurden 13 Items gebildet, wobei Innovationsklima über fünf Items operationalisiert wurde (bspw. „Unsere Krankenhausleitung fördert aktiv die Realisierung komplexer eHealth-Innovationen“). Intrapreneurship-Persönlichkeit wurde über vier Items gemessen (bspw. „Als CIO muss ich auch einmal eigene Wege gehen, um innovative eHealth-Lösungen zu realisieren“). Zur Messung der Offenheit gegenüber Nutzern wurden ebenfalls vier Items entwickelt (bspw. „Für mich als CIO ist ein tiefgreifendes und weitreichendes Verständnis der klinischen Prozesse in unserem Krankenhaus sehr wichtig“)[23] (B8, B10, B12).

Erhebung und Quantifizierung der Innovationskultur: Die Ausprägung der IT-Innovationskultur wurde in der zweiten Benchmarking-Runde ausschließlich von den CIOs abgefragt. Zur Quantifizierung der Innovationskultur wurde ein Score mit einer Skalenbreite von 1 bis 100 Punkten gebildet. Die Scorebildung basierte auf Ergebnissen einer Hauptkomponentenanalyse (B8). Die interne Konsistenz für die Sub-Dimension Innovationsklima war zufriedenstellend ($\alpha = 0{,}78$). Für die Subdimension Intrapreneurship und Offenheit gegenüber Nutzern ergaben sich geringere, allerdings akzeptable Werte ($\alpha = 0{,}64$ bzw. $\alpha = 0{,}52$). Aufbauend auf diesen Ergebnissen und im Sinne der inhaltlichen Skalierung wurde das Itemset zur Erfassung der IT-Innovationskultur in der dritten Benchmarking-Runde auf 50 Items ausgeweitet. Ebenfalls wurde die IT-Innovationskultur in der dritten Runde zusätzlich durch die PDL und die Ärztlichen Leitung erfasst (hierfür wurden 34 weitere Items entwickelt) (B8, B10, B12).

[22] Die Definition der Intrapreneurship-Persönlichkeit orientiert sich an Pinchot (1985). Demnach sind Intrapreneure *„[...] dreamers who do. Those who take hands-on responsibility for creating innovation of any kind, within a business".*

[23] Die beispielhaft aufgezeigten Items wurden frei aus der englischen Veröffentlichung (B8) übersetzt.

5.3 Modelle

Als Erklärungsmodell für den Realisierungsgrad komplexer eHealth-Innovationen wurde ein zweidimensionaler Ordnungsrahmen entwickelt. Das Modell erklärt einerseits, was zu welchem Zeitpunkt optimale Rahmenbedingungen für die Realisierung komplexer eHealth-Innovationen darstellen. Auf der anderen Seite erklärt das Modell, wie sich diese Rahmenbedingungen auf den technischen Reifegrad auswirken können. Das Modell baut auf den vorab beschriebenen Konstrukten auf (vgl. Kapitel 5.1) und stellt mögliche Zusammenhänge zwischen diesen her. Die Modellierung orientierte sich auf der einen Seite an dem aktuellen wissenschaftlichen Erkenntnisstand (Rigorosität). Auf der anderen Seite wurde das Modell empirisch über hypothesenprüfende Statistiken validiert bzw. weiterentwickelt. Die Analysen basierten dabei auf Daten, die innerhalb der Benchmarking-Runden aus der Krankenhauspraxis erhoben wurden (Relevanz). Ausgehend von der eingangs beschriebenen Grundannahme, dass komplexe eHealth-Innovationen in Krankenhäusern tiefgreifende, weitreichende und langfristige Umwandlungsprozesse erfordern (Grundannahme 2), wurde in Anlehnung an Rogers (2010) zwischen einer *Initialisierungs-*, *Implementierungs-* und *Institutionalisierungsphase* unterschieden. Diese Phasen bauen idealtypisch aufeinander auf. In dem Erklärungsmodell bildeten diese Phasen die horizontale Achse. In der vertikalen Achse wurden die Konstrukte (technischer Reifegrad, IT-Management, IT-Governance, IT-Innovationskultur) den drei Phasen zugeordnet.

Initialisierungsphase: „*In the pre-implementation phase are sown the seeds of success or failure*“ (Keshavjee et al. 2006, S. 4). In der Initialisierungsphase werden innovative eHealth-Anwendungen erstmals von den IT-Stakeholdern wahrgenommen, Nutzungspotenziale eruiert und Investitionsentscheidungen getroffen. Wie eingangs nach Keshavjee et al. (2006) zitiert, sind die hier getroffenen Investitionsentscheidungen nur schwer zu revidieren und daher besonders erfolgskritisch für den weiteren Verlauf des Adoptionsprozesses. Entsprechend ergibt sich die Frage, welche Rahmenbedingungen die richtigen Investitionsentscheidungen, bzw. die richtige Auswahl an neuen KIS-Attributen (insb. Hard- und Software) begünstigen. Nach Haux et al. (2013) orientieren sich die Investitionsentscheidungen in dieser Phase idealtypisch an einer IT-Strategie, die gemeinsam mit den Vertretern kritischer IT-Stakeholder erarbeitet wurde. Innerhalb entsprechender Projektportfolios werden Krankenhausbereiche definiert, in denen zukünftig Digitalisierungsmaßnahmen durchgeführt werden sollen. Gleichzeitig führt das IT-Management eine strategiekonforme Architektur-, Finanz- und Investitionsplanung durch (Haux et al. 2013). Die Auswahl neuer KIS-Attribute muss andererseits die spezifischen Herausforderungen klinischer Prozesse berücksichtigen (Smaltz et al. 2006) (B8, B10, B12). Wie in B5 gezeigt werden konnte, kann die frühzeitige Kommunikation zwischen der IT-Abteilung und den potenziellen Anwendern die weiteren Phasen des Adoptionsprozesses erfolgskritisch determinieren. Entsprechend muss das IT-Management in der Initialisierungsphase Bedarfsanalysen durchführen (z.B. Status Quo Bewertungen, Systemspezifikation, Systemauswahl) und dabei in besonderer Weise die Anforderungen klinischer Abläufe berücksichtigen (Ammenwerth et al. 2006). In B10 konnte gezeigt werden, dass entsprechende Managementaktivitäten von einer ausgeprägten IT-Governance profitieren können.

Indem die CIOs durch eine geeignete hierarchische Positionierung die notwendigen Entscheidungsbefugnisse erhalten und andererseits über ein ausgewiesenes IT-Budget verfügen, können sie IT-Projekte schneller initiieren und somit besser auf Marktentwicklungen und Anwenderbedürfnisse reagieren. Damit digitale Wettbewerbsoptionen (Rasche 2017) frühzeitig wahrgenommen werden können, profitieren die Krankenhäuser zudem von einer ausgeprägten Intrapreneurship-Persönlichkeit des CIOs (B10). Im Zusammenhang hiermit konnte in B12 gezeigt werden, dass die CIOs besonders dann innovativ wirken können, wenn ihr Handeln auf einer ausgeprägten strategischen Partnerschaft mit der Krankenhausleitung basiert. Neben der Intrapreneurship-Persönlichkeit des CIOs fördert aber auch eine ausgeprägte Offenheit gegenüber Anwendern das frühzeitige Erkennen digitaler Optionen, da gerade in Krankenhäusern oftmals die Kliniker eHealth-Innovationen anstoßen (Cresswell et al. 2011, Goh et al. 2011) (B8, B12). Die Bedeutung einer ausgeprägten Kommunikation zwischen dem IT-Management und den klinischen Anwendern konnte in B5 nachgewiesen werden. Die so beschriebene Kombination professioneller Managementhandlungen, etablierten Governancestrukturen und ausgeprägter Innovationskultur führt auf technischer Ebene idealtypisch zu einer hohen *Strukturqualität*, da sowohl unter strategischen, als auch unter operativen bzw. anwenderseitigen Gesichtspunkten zeitnah die richtigen KIS-Attribute im Sinne digitaler Wettbewerbsoptionen angeschafft werden.

Implementierungsphase: Die Implementierungsphase baut auf der Initiierungsphase auf (Rogers 2010). Hier werden die eHealth-Innovationen (bspw. neue IT-Funktionen oder Endgeräte) technisch integriert und in die klinische Praxis überführt (Avgar et al. 2012, Keshavjee et al. 2006). Wie erfolgreich diese technische und organisatorische Implementierung verläuft, hängt in besonderer Weise von der Professionalität des Projektmanagements ab (Haux et al. 2013). Während die technische Installation bspw. durch die Nutzung von Workflowmanagementsystemen möglichst schnittstellenneutral auf eine optimale klinische Informationslogistik bzw. eine hohe *Prozessqualität* abzielt (Lenz und Reichert 2007), müssen auf der anderen Seite sowohl die klinischen Anwender als auch die IT-Mitarbeiter im Umgang mit den neuen Technologien geschult werden. Auch hier profitiert das IT-Management von einer ausgeprägten IT-Governance und Innovationskultur (B10). Nur wenn die CIOs über ausreichende Entscheidungsbefugnisse verfügen (hierarchische Positionierung) können IT-Projekte im oben beschrieben Sinne geplant und durchgeführt werden (Thatcher 2013). Gleichzeitig unterstützt eine hohe organisationale Lernfähigkeit und die Einbindung klinischer Meinungsführer die Implementierung (Avgar et al. 2012) (B12).

Institutionalisierungsphase: In der Institutionalisierungsphase gehen die eHealth-Innovationen in den klinischen Alltag über und werden hierbei idealtypisch anstelle vorangegangener Lösungen genutzt (Avgar et al. 2012, Keshavjee et al. 2006). Der Erfolg der Institutionalisierung ergibt sich darüber, inwiefern die neuen Technologien nachhaltig durch die Kliniker als nutzenstiftend wahrgenommenen werden (*Ergebnisqualität*) (Goh et al. 2011, Otieno et al. 2007). Vor diesem Hintergrund gehört es zu den zentralen Aufgaben des IT-Managements, den Einsatz der neuen eHealth-Anwendungen auf operativer Ebene durch Evaluationsstudien, wie bspw. Usability Studien oder Anwenderbefragungen, zu begleiten (Haux et al. 2013). In B4 konnte gezeigt werden, dass in den Krankenhäusern insbesondere diese Aktivitäten selten durchgeführt werden. Auf strategischer Ebene erfolgt idealtypisch ein strategisches Monitoring, um den Beitrag der IT-Investitionen gegenüber der KHL darstellen zu können (Haux et al. 2013). Während Evaluationsstudien und Monitorings zum einen Fehlentwicklungen frühzeitig aufdecken und entsprechende Gegenmaßnahmen motivieren können (Ammenwerth et al. 2007), dienen sie auf der anderen Seite im Sinne eines Benefit-Managements zum Nachweis positiver Outcomes (Thatcher 2013). Neben den beschriebenen Aktivitäten führt das IT-Management innerhalb der Institutionalisierung fortwährende Trainings durch, um Anwendungsschwierigkeiten frühzeitig erkennen und begegnen zu können (Haux et al. 2013). Auch die Managementhandlungen in der Institutionalisierungsphase werden durch ausgeprägte Governancestrukturen einerseits und einer hohen Innovationskultur andererseits unterstützt (B9, B10, B12). Auf technischer Ebene kann sich im Kontext der so beschriebenen Rahmenbedingungen eine hohe *Ergebnisqualität* ergeben. Die Institutionalisierungsphase geht in einem zyklischen Prozess in die Initialisierung neuer e-Health Innovationen über (Keshavjee et al. 2006).

Schließlich ist davon auszugehen, dass effizienz- und qualitätssteigernde Effekte erst erwartet werden können, wenn alle drei Phasen erfolgreich verlaufen und eine hohe technische Ergebnisqualität erzielt wurde (Buntin et al. 2011, Jones et al. 2014). Abbildung 6 stellt das Erklärungsmodell zur Realisierung komplexer eHealth-Innovationen grafisch dar:

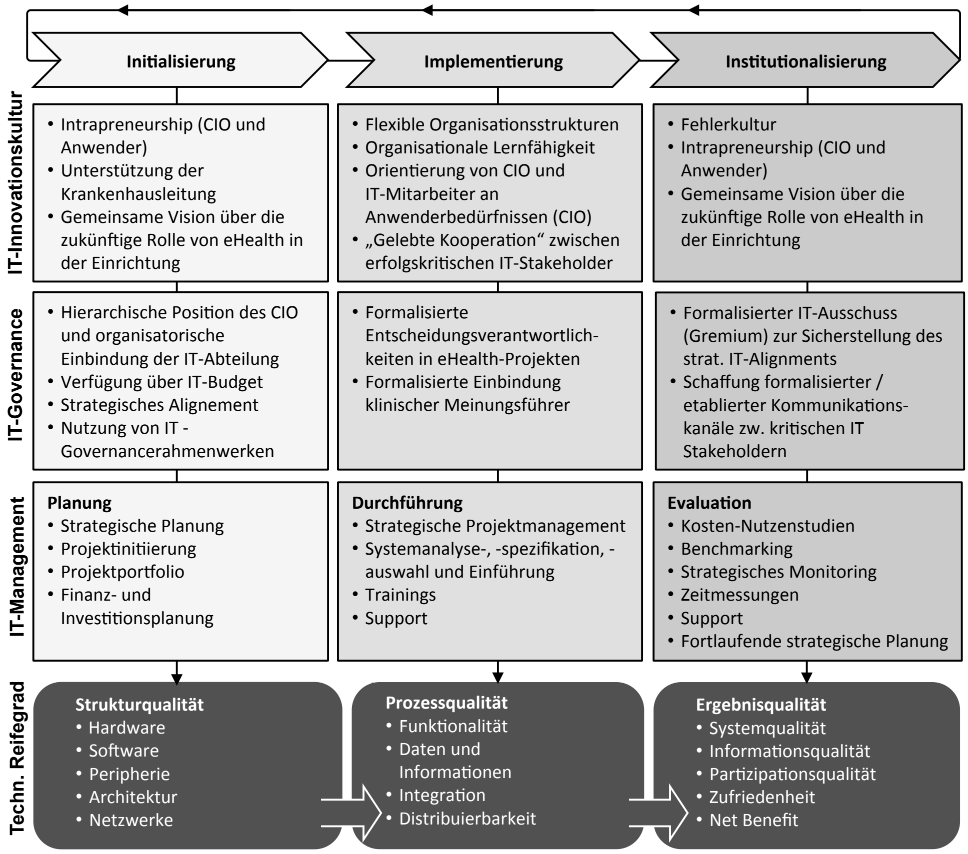

Abbildung 6. Erklärungsmodell für die Realisierung komplexer eHealth-Innovationen

5.4 Methoden

Damit den Benchmarking-Stakeholdern vergleichsgruppenspezifische, entscheidungsunterstützende Informationen weitergegeben werden können, sollten die entwickelten Methoden insbesondere drei Fragen beantworten: Erstens, wo stehen die Krankenhäuser mit ihrer IT und inwiefern haben sie ihre strategischen IT-Ziele bereits erreicht (Status Quo)? Zweitens, wo können sie sich noch verbessern, auch im Vergleich zu ihren Mitbewerbern (Schwachstellenanalyse) und drittens, wie können sie sich verbessern (Best Practices und Handlungsempfehlungen)? (vgl. Kapitel 1). Nachfolgend soll beschrieben werden, wie die entsprechenden Informationen den Benchmarking-Stakeholdern zur Verfügung gestellt wurden. Wie bereits in der vorangegangenen Ergebnisdarstellung, soll auch hier darauf eingegangen werden, wie die Methoden im Verlauf der drei Benchmarking-Runden angepasst und weiterentwickelt wurden.

5.4.1 Status Quo und Optimierungspotenziale

In der ersten Benchmarking-Runde erfolgte die Visualisierung der Key-Performance-Indikatoren in Form gängiger deskriptive Diagramme (insb. Balken- Kreis-, und Säulendiagramme) (B1). Ausgehend von Verbesserungsvorschlägen, welche die Teilnehmer im Rahmen einer anschließenden Evaluation gegeben haben (B1), wurde in der zweiten Runde ein mehrstufiges Visualisierungskonzept erarbeitet und umgesetzt (B2, B3, B6). Die Konzeption orientierte sich dabei an drei Anforderungen: Erstens, die Benchmarking-Teilnehmer sollen die für sie wichtigsten KPIs flexibel aus einer Reihe von Indikatoren auswählen können. Zweitens, die KPIs sollen so präsentierten werden, dass sie auch für klinische IT-Stakeholder nachvollziehbar sind (vgl. Kapitel 2). Drittens, die Teilnehmer sollten die Ergebnisse schnell erfassen können (B6). Vor diesem Hintergrund wurden für die Entwicklung des Visualisierungskonzepts gängige Gestaltungsprinzipen wie bspw. Differenziertheit, Kompaktheit und Salienz herangezogen (Preim und Dachselt 2010) (B6).

Die erstellte Visualisierungssystematik wurde zuerst an dem WCS getestet (vgl. Kapitel 5). Damit die hierarchische Struktur des Composite Scores graphisch abgebildet werden konnte, wurde ein Drei-Stufen-Modell als Ordnungsrahmen erarbeitet (B6). Hierdurch konnten alle Aggregationsebenen des Scores dargestellt werden (vgl. Abbildung 5).

Für die vergleichsgruppenspezifische Präsentation der KPIs wurde zum einen die Krankenhausgröße (fünf Bettenklassen, z.B. „1-199 stationäre Betten“) und zum anderen die Trägerschaft (öffentlich vs. privat) als Unterscheidungskriterien herangezogen (B2, B3, B6). Die Auswahl dieser Merkmale orientierte sich an der aktuellen Studienlage und wurde zudem im Hinblick auf die anvisierten Benchmarking-Gruppen mehrfach als signifikante Differenzierungsmerkmal bestätigt (B3, B9)[24]. Ausgehend von dem Visualisierungskonzept wurden die Ausprägungen der einzelnen Items (3. Ebene, Abbildung 5) auch in der zweiten Runde in Form von Balken-, Kreis-, und Säulendiagrammen dargestellt. Für die Darstellung der Score-Werte wurden neue Grafiken entwickelt (B6).

Exemplarisch wird in Abbildung 7 die Innovation View dargestellt. In Anlehnung an die *Diffusion of Innovation Theory* konnte durch die Grafik der relative Innovationsgrad der Teilnehmer angezeigt werden (vgl. Kapitel 2). Zur Erstellung der Grafik wurden die Vergleichsgruppenwerte entsprechend der, von Rogers (2010) vorgeschlagenen, Referenzkategorien zugeteilt[25]. Hierauf aufbauend wurde der individuelle Wert des Teilnehmers angezeigt. In dem präsentierten Beispiel erreichte der Benchmarking-Teilnehmer innerhalb der zweiten Reifegradstufe (WCS bzw. Prozessqualität) 22 von 40 Punkten. Obwohl sich der Teilnehmer somit absolut betrachtet im Mittelfeld befand, lag sein relativer Innovationsgrad im unteren Bereich (B2, B6). Ausgehend von dieser grundsätzlichen Statusanalyse, konnten konkrete Optimierungspotenziale auf den unteren Aggregationsebenen, bzw. der Item-Ebene identifiziert werden (B6).

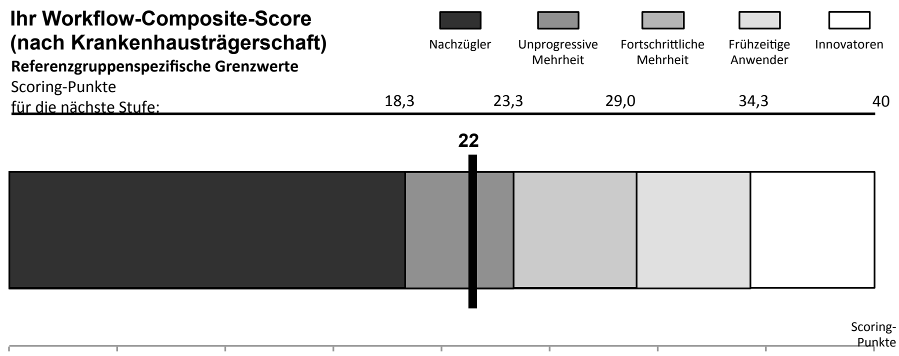

Abbildung 7. Status Quo und Schwachstellenanalyse auf Basis der Innovation View

[24] Der Einfluss der Krankenhäusergröße und -trägerschaft auf die IT-Ausstattung wurde in verschiedenen IT-Adoptionsstudien nachgewiesen (bspw. Hikmet et al. 2008, Fonkych et al. 2005).

[25] Ausgehend von der Annahme, dass sich Innovationen innerhalb eines sozialen Systems langsam verbreiten, unterscheidet Rogers (2010) zwischen fünf Klassen von Adoptern und teilt diesen relative Referenzwerten zu. Demnach ergeben sich in einer Population und im Hinblick auf die Annahme (Adoption) von Innovationen idealtypisch folgende Cluster: Innovatoren: 2,5%; frühzeitige Anwender: 13,5%; fortschrittliche Mehrheit 34,0%; unprogressive Mehrheit 34,0% und Nachzügler (16,0%).

5.4.2 Best Practices und Handlungsempfehlungen

Neben der vorab beschriebenen Darstellung von Status Quo- und Schwachstellenanalysen wurde eine Methode konzipiert, mit der die Teilnehmer des Verfahrens im Rahmen ihrer Vergleichsgruppe Best Practices identifizieren und Handlungsempfehlungen ableiten können. Die Methode kombiniert die Systematik der vorab dargestellten Innovation View mit dem, unter Kapitel 5.3 beschriebenem, Erklärungsmodell. Aufbauend auf der Zuordnung zu den Referenzkategorien (s.o.) werden zwischen den Innovatoren und den Nachzüglern einer Gruppe spezifizierte Merkmalskombinationen algorithmusbasiert im Hinblick auf Unterschiede getestet. Die darunter liegende Prüfsystematik orientiert sich an dem erstellten Erklärungsmodell, indem der technischen Reife (Struktur-, Prozess- und Ergebnisqualität) organisatorische Rahmenbedingungen gegenübergestellt werden (IT-Management, IT-Governance, IT-Innovationskultur)(vgl. Kapitel 5.3)[26]. Die Unterschiedstests können dabei sowohl auf Ebene der Items, als auch auf Ebene der Scores erfolgen (bspw. Prozessqualität und Professionalisierungsgrad).

In Abhängigkeit von seinen individuellen Ausprägungen werden dem Teilnehmer schließlich die Merkmale angezeigt, in denen er sich signifikant von den Innovatoren unterscheidet. Hierdurch ergeben sich Hinweise auf Best Practices bzw. Handlungsempfehlung. In Abbildung 8 wird die konzipierte Methode dargestellt. In dem Beispiel könnte der betreffende IT-Entscheider, ausgehend von den Ergebnissen, verstärkt evaluierende Managementaktivitäten durchführen, da diese im Gegensatz zu den Innovatoren in der Vergleichsgruppe noch nicht aktiv verfolgt werden. Für die dritte Runde des Verfahrenswird aktuell eine webbasierte Visualisierung umgesetzt, in der diese Best Practice Methode eingebunden werden soll.

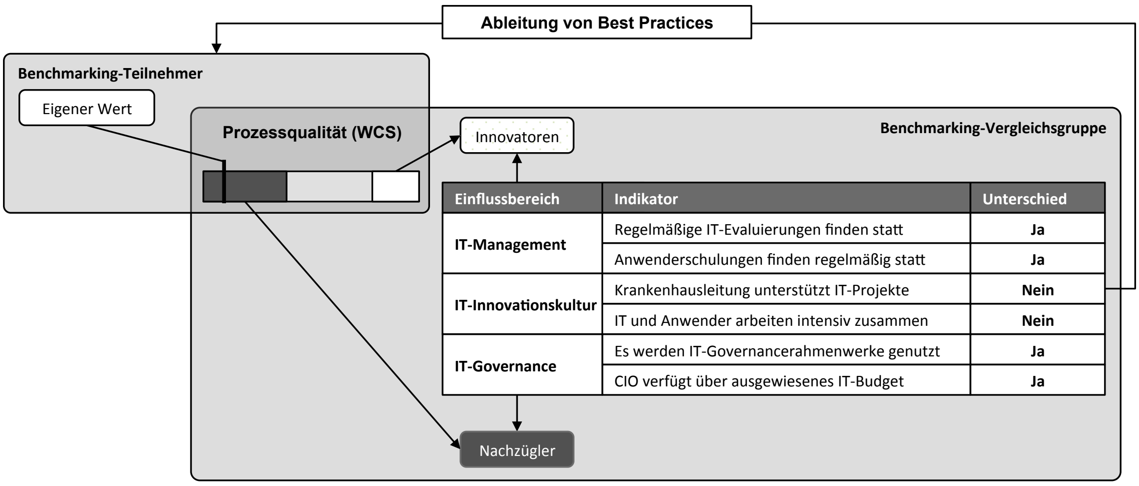

Abbildung 8. Methodisches Konzept zur Ableitung von Best Practices

[26] Im Zuge der Evaluierung muss getestet werden, ob die Vergleichsgruppen durch das erneute Clustern nach wie vor groß genug sind, um statistische Verfahren durchführen zu können (Bortz und Döring 2007). Alternativ zur Clusterung nach den Referenzkategorien von Rogers (2010) kann ein Mediansplitting durchgeführt werden. Neben den vorgeschlagenen Unterschiedstests können auch univariate bzw. multivariate Zusammenhangsanalysen die vergleichsgruppenspezifische Identifikation von Best Practices ermöglichen. Abgesehen von der modellbasierten Prüfsystematik sind auch andere Analyseformen denkbar (z.B. neuronale Netze, die datenbasiert Zusammenhänge eruieren).

5.5 Instanziierungen und Evaluation

Die technische Umsetzung erfolgte in den ersten zwei Benchmarking-Runden über eine Auswahl heterogener Softwareanwendungen. Die Datenerhebung wurde über die externe Datenerhebungsplattform *Unipark* durchgeführt. Die Datenhaltung erfolgte über Rohwerttabellen im .spv und .xls Format und die Analyse und Visualisierung wurde über das Statistiktool *IBM SPSS Statistics 24* und das Tabellenkalkulationsprogramm *Excel 2011* durchgeführt (B1, B3, B6). In der dritten Benchmarking-Runde wurden die einzelnen Systemkomponenten zur Datenerhebung-, -haltung, -analyse und -visualisierung in eine integrierte Systemarchitektur überführt. Im Sinne der angestrebten Ressourceneffizienz (vgl. Kapitel 2) wurde das Systemdesign vollständig mit Open Source Komponenten umgesetzt. So wurde das System auf einem *Ubuntu Server 16.04* mit *PostgreSQL 9.6* implementiert. Die Datenintegration zwischen den einzelnen Schichten wurde mit *Pentaho Data Integration 7* implementiert. Für erste longitudinale Berechnungen und Visualisierungen wurde die Statistiksoftware *R 3.3.2* mit *ggplot2 2.2.1* eingesetzt. Primärdaten wurden aus *LimeSurvey 2.54.3* und aus archivierten Umfragedatensätzen im .spv Format aus vorherigen Benchmarking-Runden extrahiert. Eine nähere Beschreibung der Architektur und des Datenmodells findet sich in B11 und B13.

Die Benchmarkingplattform wurde nach jeder Runde evaluiert. So wurden nach der ersten Runde unter anderem die Nutzungsarten der Benchmarks abgefragt. Nach Angaben der Teilnehmer waren dies vor allem die „Bestimmung der Wettbewerbsposition“ (48,5%), die „Diskussion mit erfolgskritischen IT-Stakeholdern“ (23,4%) und das „strategische IT-Alignment“ (21,8%) (Einfachzählung, n=51) (B1). In der zweiten Runde konnten die Teilnehmer die Nützlichkeit der zurückgespiegelten Informationen und die Visualisierung dieser bewerten. In Abbildung 9 werden die Ergebnisse der Evaluation dargestellt. Es zeigte sich, dass alle KPI-Visualisierungen als „sehr nützlich“ oder „nützlich“ eingeschätzt wurden (B6).

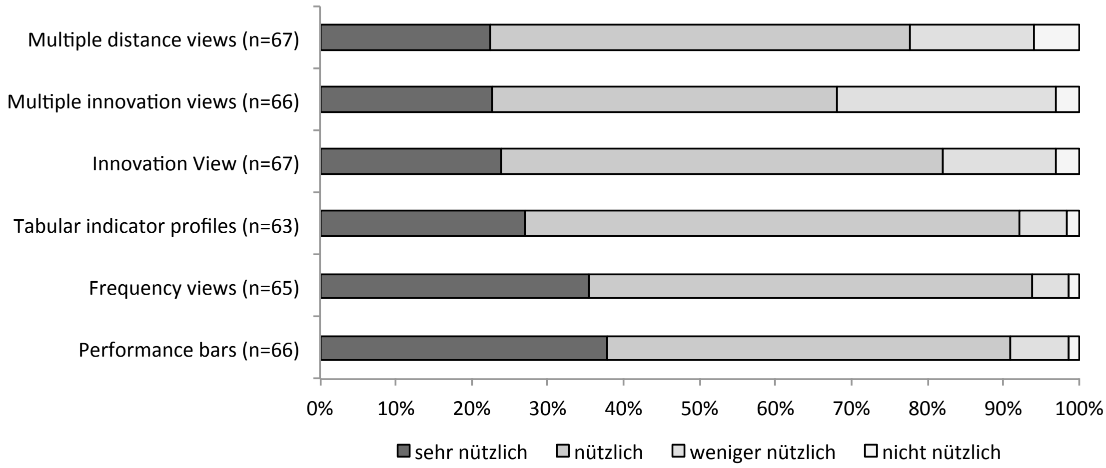

Abbildung 9. Evaluation der KPI-Visualisierung

6 Implikationen

Das vorgeschlagene *innovationskatalytische Prinzip* konnte in der vorliegenden Arbeit erfolgreich in Form einer skalierbaren Benchmarkingplattform umgesetzt werden, wodurch sich eine neue Methode zur Erforschung innovativer Informationstechnologien ergibt. So kann davon ausgegangen werden, dass sich das Verfahren beliebig auf andere Anwendungs- bzw. Forschungsfelder übertragen lässt, in denen innovative Technologien eingesetzt werden sollen. Hierbei ist hervorzuheben, dass die vorgeschlagene Methodik auf dem etablierten Rahmenkonzept der Design Science von Hevner et al. (2004) aufbaut und dieses technisch fundiert. Hierdurch ergeben sich insbesondere für die Disziplin der Wirtschaftsinformatik vielversprechende Anwendungsmöglichkeiten. Potenzielle Einsatzgebiete für die Plattform erscheinen dabei insbesondere wissensintensive Branchen, in denen IT basierte Prozess-, Service- und Produktinnovationen inkrementell entstehen und in denen gleichzeitig ein Innovationsgefälle zwischen den Marktteilnehmern existiert. Beispiele hierfür finden sich vor allem in (halb-) öffentlichen Bereichen (z.B. Hochschulen, Versicherungen, Pflegeeinrichtungen, Einrichtungen der kommunalen Verwaltung). Aber auch für andere Sektoren wie bspw. für die Fertigungsbranche besitzt der Einsatz eines skalierbaren Verfahrens *innovationskatalytisches* Potenzial[27]. Unabhängig von innovativen Informationssystemen kann das Verfahren auch in anderen Forschungsgebieten eingesetzt werden, in denen komplexe und innovative Phänomene untersucht werden sollen. Voraussetzung hierfür ist, dass diese einerseits auf praktische Umsetzungsprobleme und andererseits auf ein wissenschaftliches Erkenntnissinteresse stoßen.

Durch die prototypische Anwendung im Krankenhausbereich konnten zudem konkrete wissenschaftliche Erkenntnisse für die Beschreibung und Erklärung komplexer eHealth-Innovationen gewonnen werden. So wurde im Rahmen dieser Dissertation erstmals eine umfassende Beschreibungs- und Erklärungssystematik für diese Phänomene entwickelt und validiert. Gegenüber bisherigen Ansätzen konnte hierbei der technische Reifegrad über ein Stufenmodell multiperspektivisch beschrieben und erfasst werden. Die besondere Berücksichtigung des Prozessbezuges komplexer eHealth-Innovationen kann hierbei hervorgehoben werden. Darüber hinaus wurden mit dem IT-Management, der IT-Governance und der IT-Innovationskultur erstmals erfolgskritische Rahmenbedingungen klassifiziert, differenziert beschrieben und in reliable und valide Erhebungsinstrumente überführt. Das aufgestellte Erklärungsmodell konnte unter anderem zeigen, dass der Professionalisierungsgrad des IT-Managements in besonderer Weise von dem Intrapreneurship der CIOs determiniert wird. Auch konnte nachgewiesen werden, dass in der Initiierungsphase komplexer eHealth-Innovationen Informationsgradienten zwischen CIOs und Klinikern entstehen, die durch eine frühzeitige Partizipation der Anwender verringert werden kann.

Die praktischen Implikationen der umgesetzten Benchmarkingplattform ergeben sich analog zu den theoretischen Implikationen. Durch die Skalierbarkeit des Ansatzes konnte in besonderer Weise die Kontingenz innovativer Informationstechnologien berücksichtigt werden, wodurch die „Konstruktion möglicher Welten“ (Frank 2009, S. 168) explizit ermöglicht wurde. Exemplarisch konnte das für die Krankenhäuser nachgewiesen werden, indem die kontinuierliche Rückspiegelung entscheidungsunterstützender Informationen die Verwirklichung komplexer eHealth-Innovationen förderte. Neben dem Krankenhauswesen kann die Plattform im Rahmen zyklischer Verbesserungsprozesse auch für Unternehmen anderer Branchen praktische Hinweise über Ursache- und Wirkungsweisen innovativer Technologien liefern. Wie bereits erläutert, erscheint hierbei insbesondere der (halb-) öffentliche Sektor ein vielversprechendes Anwendungsgebiet zu sein.

[27] Die Anwendung der Austauschplattform ist dabei nur vielversprechend, wenn es sich bei den betrachteten IT-Innovationen nicht um Kernkompetenzen handelt, die von den jeweiligen Wirtschaftsakteuren im Sinne von *first mover advantages* (Resourced Based View) genutzt werden wollen (Drew 1997).

Nicht zuletzt sind auch diverse Geschäftsmodelle denkbar, die sich aus dem dargestellten Benchmarkingverfahren ergeben können. Neben vielfachen Möglichkeiten der Sekundärdatenverwertung (Monetarisierung über Contententwicklung), könnte die Plattform bspw. auch als Akquiseinstrument für mehrstufige Beratungsdienstleistungen eingesetzt werden. Die Entwicklung einer kommerziellen, webbasierten Austauschplattform wäre hierbei nur der erste Schritt[28].

7 Limitationen

Für die verfassten Forschungsbeiträge ergeben sich verschiedene methodische und konzeptionelle Limitationen. Diese beziehen sich vor allem auf die konstituierenden Artefakte des Verfahrens und sollen nachfolgend in entsprechender Gliederung dargestellt werden.

Konstrukte: Obwohl die Konstrukte zur Beschreibung des Realisierungsgrades komplexer eHealth-Innovationen in Anlehnung an etablierte Methoden zur Skalenentwicklung erstellt wurden, konnten die von MacKenzie et al. (2011) geforderten Entwicklungsschritte nicht für alle Indizes gleichermaßen durchgeführt werden. So wurde zum einen die Strukturqualität des technischen Reifegrades bisher nur über singuläre Merkmale erfasst und dargestellt. Gleiches gilt für die IT-Governance. Während die Güte der Messinstrumente zur Erfassung der Prozessqualität und der IT-Innovationskultur bereits validiert werden konnte, muss dieser Nachweis im Hinblick auf die Struktur- und Ergebnisqualität, das IT-Management und die IT-Governance, noch erbracht werden. Darüber hinaus umfasst die Operationalisierung der Ergebnisqualität bisher noch nicht die Dimension *Use*, wie sie im *Information System Success Modell* vorgeschlagene wird. In der dritten Benchmarking-Runde wurden zwar entsprechende Skalen gebildet, deren Güte gilt es jedoch noch zu überprüfen. Weiterhin muss die Unabhängigkeit der Konstrukte bspw. durch faktoranalytische Verfahren nachgewiesen werden. So kann vermutet werden, dass IT-Governance und IT-Management nicht überschneidungsfrei operationalisiert wurden. Darüber hinaus kann die vorgeschlagene Operationalisierung und subjektive Erfassung der Prozessqualität methodisch hinterfragt werden. Insbesondere in gestaltungsorientierten Evaluationsansätzen wird die Prozessqualität über objektive Parameter wie bspw. Durchlaufzeiten erfasst. Eine Weiterentwicklung des Verfahrens unter Berücksichtigung entsprechender Perspektiven erscheint auch im Hinblick auf die Akzeptanz der Benchmarking-Plattform geboten. Grundsätzlich könnten zukünftig verstärkt offene Fragetypen eingesetzt werden, damit auch radikale Innovationen und kontingente Entwicklungen erfasst werden. Obwohl sich diese Fragetypen nicht für den statistischen Vergleich eignen, können sie die Erhebungsinstrumente im Sinne der inhaltlichen Skalierung erweitern.

Modelle: Das Erklärungsmodell wurde in weiten Teilen deduktiv, bzw. theoriebasiert, entwickelt. Aufbauend auf den bereits durchgeführten Hypothesenprüfungen, müssen die aufgestellten Zusammenhänge verstärkt auf Basis empirischer Daten überprüft werden. So wurde insbesondere der Zusammenhang zwischen organisatorischen Rahmenbedingungen und technischem Reifegrad bisher nur ansatzweise überprüft. Neben diesen, im Modell horizontal dargestellten, Ursache- und Wirkungszusammenhängen, gilt es auch die vertikalen Zusammenhänge empirisch zu testen. Insbesondere der unterstellte monokausale Zusammenhang zwischen der Prozess- und Ergebnisqualität kann hierdurch fundiert werden. Gleiches gilt für den prozesshaft modellierten Zusammenhang zwischen den Managementhandlungen einerseits und den Phasen des Adoptionsprozesses andererseits. So wird durch diese Annahmen die empirische Wirklichkeit vermutlich zu stark simplifiziert, da in jeder Phase sowohl planende, durchführende als auch evaluierende Aktivitäten durchgeführt werden können. Eine Differenzierung nach operativen, taktischen und strategischen Aktivitäten könnte den erklärenden Ansatz des Modells erweitern.

[28] Entsprechende Monetarisierungspotenziale bzw. Geschäftsmodelle erfordern eine strenge Berücksichtigung ethischer Leitlinien. So dürften bspw. Sekundärdatenanalysen nur in anonymisierter Form und unter Zustimmung der Benchmarking-Teilnehmer erfolgen. Ebenfalls ist zu berücksichtigen, dass die wissenschaftlich unabhängige Durchführung ein wesentliches Element des vorgeschlagenen Konzepts darstellt.

Methoden: Das vorgeschlagene Visualisierungskonzept kann in verschiedener Hinsicht weiterentwickelt werden. Zum einen zeigten Experteninterviews, dass IT-Entscheider in Krankenhäusern heterogene Anforderungen an die KPI-Visualisierung stellen, grundsätzlich aber gängige Darstellungen bevorzugen (bspw. Tabellen, Säulen- und Kreisdiagramme). Basierend auf einer webbasierten Visualisierung könnte daher eine breitere und gleichzeitig flexible Auswahl an Darstellungsoptionen angeboten werden. Die konzipierte Methode zur Ableitung von Best Practices wurde bisher noch nicht technisch umgesetzt und evaluiert. Auch dieser Schritt kann auf Basis der webbasierten Visualisierung erfolgen. Im Hinblick auf eHealth-Innovationen erscheint darüber hinaus eine kombinierte Darstellung technischer und organisatorischer Merkmale sinnvoll. Ansätze hierfür bietet die Balanced-Scorecard-Systematik.

Instanziierung: Die Umsetzung der integrierten Data-Warehouse Plattform kann in verschiedener Hinsicht weiterentwickelt werden. Beispielsweise könnten vordefinierte ETL-Prozesse standardisierte und regelmäßige Abfrage vereinfachen. Da es aufgrund der Umfragelänge in den bisherigen Benchmarking-Runden zu hohen Abrecherquoten gekommen ist, könnte zukünftig der Einsatz deutlich kürzerer Fragebögen getestet werden. Hierbei wäre vor allem zu prüfen, inwiefern sich die entsprechenden Datensätze sinnvoll über einen einheitlichen Identifikationsschlüssel verknüpfen lassen. Schließlich müssten im Hinblick auf die webbasierte Visualisierung der KPIs weitere Web-Front-Ends entwickelt werden. Dabei kann auch das Angebot einer offenen Austauschplattform (z.B. als „CIO-Forum“) mitgedacht werden.

Unabhängig von den Artefakten dürfen aber auch grundsätzliche, konzeptionelle Limitation des vorgestellten Ansatzes nicht unerwähnt bleiben. So basierte das Verfahren auch auf der Annahme, dass Krankenhäuser aufgrund des kooperativen Wettbewerbs im Gesundheitswesen, über eine vergleichsweise hohe Bereitschaft zum Informationsaustausch verfügen. Verschiebt sich diese Perspektive, ist jedoch davon auszugehen, dass insbesondere IT-innovative Einrichtungen zunehmend weniger motiviert sind, Best Practices mit ihren Mitbewerbern auszutauschen. Schließlich können sich durch den verhaltensorientierten Ansatz der Plattform Verzerrungen ergeben. Zu nennen sind hier unter anderem der Pro-Innovation-Bias (jede Innovation gut ist) und der Recall-Bias (Selbstauskunft ist nicht immer verlässlich) (Jeyarai et al. 2006, Rogers 2010).

8 Fazit

Benchmarkings besitzen ein hohes Potenzial die Verwirklichung IT-basierter Prozess- und Serviceinnovationen zu unterstützen. Dies gilt in besonderer Weise für die Krankenhäuser, in denen die Nutzung von eHealth-Innovationen weitreichende Sprünge in Richtung einer fehlerfreien, kontinuierlicheren und effizienten Patientenversorgung versprechen. Gleichzeitig stellt der inkrementelle, komplexe und kontingente Charakter solcher Innovationen hohe Anforderung an die IT-Entscheider und somit auch an die Durchführung von Benchmarkings. Einerseits müssen die Verfahren zeitlich, räumlich und inhaltlich skalierbar sein. Andererseits bedarf es einer möglichst unabhängigen und ressourcenschonenden Durchführung.

Vor diesem Hintergrund verfolgte die vorliegende Dissertation zwei Ziele: Zum einen sollte eine skalierbare Benchmarkingplattform zur Unterstützung inkrementeller Innovationsstrategien konzipiert und entwickelt werden. Zum anderen sollte die Plattform am Beispiel der Krankenhäuser prototypisch umgesetzt werden. Die Entwicklung und Umsetzung basierte auf der Annahme eines *innovationskatalytischen Prinzips*, welches als Arbeitshypothese vorgeschlagen wurde. Das Prinzip geht davon aus, dass zwischen der Unternehmenspraxis einerseits und der Forschung andererseits ein Anreizverhältnis für einen wechselseitigen Informationsaustausch besteht. Wird auf Basis dieses Anreizverhältnisses eine Benchmarkingplattform umgesetzt, können Netzwerkeffekte entstehen, die wiederum die Skalierbarkeit des Verfahrens begünstigen: Wird das Benchmarking im Zeitverlauf zunehmend mehr genutzt, kann (1.) das entscheidungsunterstützende Informationsangebot für die Teilnehmer fortlaufend optimiert werden (bspw. durch die Möglichkeit prognostischer Trendanalysen bei langjähriger Teilnahme), (2.) der wissenschaftliche Erkenntnisstand kontinuierlich angereichert werden (insb. durch die Möglichkeit der empirischen Überprüfung von Hypothesen, Modellen und Theorien) und (3.) die Austauschplattform selber fortlaufend angepasst und weiterentwickelt werden (durch den anhaltenden Rückgriff auf praktische Anforderungen einerseits und den aktuellen wissenschaftlichen Erkenntnisstand andererseits).

Die Funktionsweise des *innovationskatalytischen Prinzips* konnte durch die Umsetzung der Plattform innerhalb von drei Benchmarking-Runden in mehrfacher Hinsicht nachgewiesen werden. So stieg zum einen die Teilnehmerzahl des Verfahrens von anfangs 59 Krankenhäusern auf 196 Teilnehmer in der dritten Runde. Diese positive Resonanz wurde durch die Evaluationen des Verfahrens bestätigt, in der die Teilnehmer sowohl die zur Verfügung gestellten KPIs als auch deren Visualisierung als hilfreich einschätzten. Nach Angaben der Teilnehmer wurden die Benchmarks insbesondere zur Bestimmung der Wettbewerbsposition, für den konstruktiven Austausch mit IT-Stakeholdern und für das strategische IT-Alignment genutzt.

Neben der praktischen Verwertung konnte der *innovationskatalytische* Mechanismus der Plattform auch im Hinblick auf die Anreicherung des wissenschaftlichen Erkenntnisstandes nachgewiesen werden. So wurden im Verlauf der drei Benchmarking-Runden und auf Basis der erfassten Daten vielfältige Erkenntnisse zur Beschreibung und Erklärung komplexer eHealth-Innovationen gewonnen und publiziert.

Schließlich konnte die Plattform in mehrfacher Hinsicht und in Bezug auf ihre vier konstituierenden Artefakte weiterentwickelt, bzw. skaliert werden. Dabei erfolgten die Anpassungen aufgrund des kontinuierlichen Praxis-Forschungs-Austausches im Sinne der, von Hevner et al. (2004) geforderten, Relevanz und Rigorosität. So wurden zum einen die Konstrukte zur Beschreibung komplexer eHealth-Innovationen im Hinblick auf ihre Operationalisierung und Quantifizierung durch Hinzunahme neuer Items und neuer Befragungszielgruppen fortwährend angepasst und erweitert. Weiterhin konnte das aufgestellte Modell zur Erklärung komplexer eHealth-Innovationen kontinuierlich validiert und angepasst werden. Auch die Methoden zur Ableitung und Visualisierung entscheidungsunterstützender Informationen wurden im Verlauf der drei Runden in mehrfacher Hinsicht optimiert. Schließlich konnte die technische Umsetzung bzw. Instanziierung des Verfahrens von einer heterogenen Systemarchitektur in der ersten Runde zu einer integrierten, Data-Warehouse basierten, Systemplattform in der dritten Runde weiterentwickelt werden. Die hierfür erstellten Datenmodelle ermöglichen nicht nur die Skalierbarkeit des Verfahrens, sondern auch eine ressourcenschonende Durchführung.

Aus den Arbeiten ergeben sich verschiedene wissenschaftliche und praktische Implikationen, wobei insbesondere die Übertragung des Verfahrens auf andere Anwendungsfelder innovativer Informationssysteme vielversprechend erscheint. Schließlich kann und konnte die Plattform die Verbreitung innovativer eHealth-Technologien in Krankenhäusern unterstützen, wodurch sich vielfältige Nutzungspotenziale für alle IT-Stakeholder ergeben - nicht zuletzt auch für die Patienten.

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Teil B – Einzelbeiträge

Beitrag 1: Developing and Trialling an Independent, Scalable and Repeatable IT Benchmarking Procedure for Healthcare Organisations

Titel	Developing and Trialling an Independent, Scalable and Repeatable IT Benchmarking Procedure for Healthcare Organisations
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Copyright	„ (..), the original author is allowed to use the Publisher version for teaching purposes. The Author may also forward the Publisher version to a small number of colleagues, and include it in a thesis or dissertation provided that this is not to be published commercially.“ https://methods.schattauer.de/en/authors/instructions-to-authors.html

Tabelle 2. Überblick Beitrag 1

Developing and Trialling an Independent, Scalable and Repeatable IT-Benchmarking Procedure for Healthcare Organisations

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Abstract

Background: Continuous improvements of IT-performance in healthcare organisations require actionable performance indicators, regularly conducted, independent measurements and meaningful and scalable reference groups. Existing IT-benchmarking initiatives have focussed on the development of reliable and valid indicators, but less on the questions about how to implement an environment for conducting easily repeatable and scalable IT-benchmarks.

Objectives: This study aims at developing and trialling a procedure that meets the afore-mentioned requirements.

Methods: We chose a well established, regularly conducted (inter-) national IT-survey of healthcare organisations (IT-Report Healthcare) as the environment and offered the participants of the 2011 survey (CIOs of hospitals) to enter a benchmark. The 61 structural and functional performance indicators covered among others the implementation status and integration of IT-systems and functions, global user satisfaction and the resources of the IT-department. Healthcare organisations were grouped by size and ownership. The benchmark results were made available electronically and feedback on the use of these results was requested after several months.

Results: 59 hospitals participated in the benchmarking. Reference groups consisted of up to 141 members depending on the number of beds (size) and the ownership (public vs. private). A total of 122 charts showing single indicator frequency views were sent to each participant. The evaluation showed that 94.1% of the CIOs who participated in the evaluation considered this benchmarking beneficial and reported that they would enter again. Based on the feedback of the participants we developed two additional views that provide more consolidated views.

Conclusion: The results demonstrate that establishing an independent, easily repeatable and scalable IT-benchmarking procedure is possible and was deemed desirable. Based on these encouraging results a new benchmarking round which includes process indicators is currently conducted.

Introduction

Impact on patient care

More and more studies are aiming to provide evidence that information technology (IT) can impact patient care and they cautiously conclude that this is the case when IT is implemented and utilised properly, e.g. electronic health record systems (EHR) [1], computerised provider order entry systems (CPOE) [2, 3] and clinical decision support systems (CDSS) [4]. These systems may facilitate access to comprehensive and detailed patient data [5], can support adherence to guideline-based care [6] and may help in improving the process of care [7]. The services they offer enfold their potential in IT-environments that allow information logistics mechanisms to provide the right data of the right patient at the right time and place to the right receiver [8]. In the best case health information systems constitute such an environment.

Systematic IT-governance

In order for IT-environments and clinical applications to operate successfully they need to be managed at the strategic, tactical and operational level [9]. It is only then that they are suitable enablers of the healthcare enterprise's strategy. On the other hand, managing IT-systems systematically, i.e. employing IT-governance methods, has a great potential of reducing the technical and social risks associated with introducing these systems [10]. IT-governance embraces decision making for the right system considering their potential for optimizing the service but also their risks for harming patients [11] and the hazards of impeding the work of clinicians [12]. Eventually, decisions have to be made for balancing alternative technical options [13] and taking into account the various requirements of the users at the level of individuals, departments and organisations [14]. Information officers therefore must ask themselves how performing their systems are and what options new systems offer to optimise the current practice [15].

Measuring IT performance

Performance indicators (PI) measure system characteristics, the degree with which these systems support the goals of the own enterprise [10, 16, 17], constitute the basis for comparing the performance of different organisations and ultimately for conducting IT-benchmarks [18]. They aim at providing advice on how to systematically improve IT-performance and encompass the following phases: 1.) selection of pertinent performance indicators (PI) [19], 2.) application of these indicators and identification of the weaknesses of the own organisation in comparison with the best of the group and 3.) development of practical actions on how to overcome the deficiencies [20]. There are no standardised methods on how to define PIs, however, there is a wealth of different approaches within and outside healthcare. COBIT (Control Objectives for Information and Related Technology) [21] and ITIL (Information Technology Infrastructure Library) [22] are the most renowned frameworks for IT-governance and industry-independent approaches that define objective and subjective PIs relating to *IT-operations and support*.

IT-benchmarking in hospitals

Other approaches are specialised for hospitals and healthcare in general, e.g. measuring *IT-sophistication* in hospitals in terms of technology, functions and of integration [23] or *IT-maturity* [24]. Other objective performance indicators looked at selected topics, such as the number of documents created and the number and type of problems derived from trouble ticket statistics [16] and the completeness and timeliness of discharge letters and the use of patient scheduling [19]. Subjective outcome measures that serve as PIs were availability, correctness and completeness, readability, usability of information, compliance with regulations, and the time needed for information processing [25]. Other authors pursue an integrated approach of subjective and objective criteria, e.g. automation and usability scores [26], a combination of indicators developed in other studies [27 referring to 25 and 19] and system, information and service quality, use and user satisfaction aggregated to an electronic medical record composite index [18]. In addition to defining the content of PIs there is the question of measuring the PIs and comparing organisations based on these PIs. Regularity,

independence, anonymity as well as a sufficiently large number of benchmark participants are characteristics stipulated in the literature that allow performance to be improved systematically [28]. Existing IT-benchmarking initiatives often only relate to individual hospitals [16, 19] or a closed group of a limited number of hospitals [14,18].
Against this background, our study aims at developing (aim 1) and trialling (aim 2) a new approach for conducting an independent, scalable and easily repeatable IT-benchmarking procedure based on the data of an established survey on health IT.

Materials and Methods

Survey based benchmark at national level

Using an established survey as a data source for composing reference groups entails several options. First, the benchmark is *scalable* in terms of the number of peers in the reference groups which can exceed the number of benchmark participants. Large reference groups help avoiding statistical flukes. Second, established surveys usually draw on a proven mechanism for developing a questionnaire, recruiting participants and analysing data. This makes them an attractive platform for benchmarks that should be easily repeated. If the survey is conducted and financed by an *independent* organisation the benchmark utilises data that are more likely to be unbiased with regard to potential influences exerted by the benchmark participants and third parties. Based on these presumptions we chose the IT-Report Healthcare [29, 30] as the platform and data source. The IT-Report Healthcare is a national survey of healthcare institutions in Germany that is also used in Austria and the Netherlands. It has been conducted regularly for ten years and is based on a sufficiently large number of respondents from hospitals of a different type, size and location. It is financed by public grants and publishes its survey results freely accessible on the Internet (www.it-report-healthcare.info).
The IT-benchmarking procedure described in the following related to the IT-Report Healthcare online survey of 1,368 chief information officers (CIOs) and other leading members of IT-staff in German hospitals, who represented 1,807 of Germany's 2,061 hospitals. In 254 hospitals, no such person could be identified either because they did not exist or because the position had been outsourced. The survey was conducted from March to July 2011. The invitation to the survey included the offer to take part in an anonymous IT-benchmarking.

Benchmarking instrument and performance indicators

The questionnaire used in the 2011 survey was a standardized instrument that consisted of 40 main questions and 9 subordinated questions on IT-systems/functions and integration, overall satisfaction with IT-systems/functions, IT-department, management issues and on various additional variables, e.g. hospital size, ownership and location. The items of this questionnaire constituted 61 raw performance indicators that could be classified mainly as structural features of the organisation and as functional features of the IT-system (Appendix A). The number of indicators exceeded the number of questions because more than half of the indicators (37) were derived from matrix questions in the survey that covered an entire range of functions. For example, the question on the implementation status of electronic decision support tools embraced the implementation status of four systems, i.e. of electronic systems for medical guidelines and clinical pathways, for clinical reminders, for alerting and for medication therapy. Two additional indicators were computed from two original questions. The remaining 22 indicators corresponded to 22 questions in the survey. Table 1 summarizes the categories of the raw indicators.

Table 1: Categories oft he 61 raw performance indicators

	main indicators			
	IT-systems/functions and integration	overall satisfaction with systems/functions	IT-department	management issues
raw performance indicator	43	1	11	6

We chose the term „performance indicator“ in analogy to Hübner-Bloder and Ammenwerth [17] who describe among others the „functional range of a system“ as a performance indicator. By „performance“ we therefore understand the „capability“ of a system not exclusively its „execution“ or „behaviour“. Similar indicators for measuring „system quality“ were captured in other studies by validated instruments [18, 23].

Establishing reference groups on validated characteristics

All 193 hospitals that responded to the survey served as a reference data platform for the IT-benchmark. These hospitals represented organisations of all different sizes, of different ownerships and were dispersed throughout Germany. Features that were meaningful descriptors of the reference groups were identified on the basis of univariate and multiple regression analyses. *Hospital size*, *ownership*, *IT-department*, *relationship with IT-vendors* and *IT-strategy* proved to be significant predictors for the number of IT-systems and could be confirmed in an independent analysis [31, 32].

Among these five predictors *hospital size* and *ownership* were so-called context factors, i.e. stable factors that could not be changed within a short time frame. They were used to form the two reference groups for each hospital that was benchmarked: *ownership* embraced the attributes “public” and “private” and *hospital size* the classes “up to 199”, “200 to 399”, “400 to 599”, “600 to 799” and “800 and more” beds. The number of classes and the class width was chosen on the ground of balancing the chance of getting enough members per group and of building meaningful groups.

Measuring and visualising the indicators

For each benchmark participant, the 61 raw performance indicators were presented in comparison to the ones of the size and of the ownership reference group.

These comparisons were visualised in the so-called *single indicator frequency views*, i.e. frequency charts (bar or pie charts) for each of the 61 raw performance indicators within the reference group showing the bar or pie section that belonged to the particular category of the benchmark participant in dark grey (Fig. 1 to 3). The implementation status of clinical systems was measured by a 4-point-Likert scale from “no implementation” to “completely implemented in all units” (clinical systems – example see Fig. 1), the status of the electronic patient record system by a 5-point-Likert scale (Fig. 2) and finally the status of administrative system by a 3-point-Likert scale from “no implementation” to ”completely implemented”. Different Likert scales were employed for measuring the implementation status of clinical and administrative systems because we distinguished between the implementation status of clinical systems “in all clinical units” and “in at least one but not all clinical units”. This distinction did not apply to administrative systems, which could be implemented in one department only. The scale for measuring the implementation status of the electronic patient record corresponds to the scale of previous surveys of the IT-Report Healthcare and was retained to be downward compatible. The frequency data for each raw indicator were extracted from SPSS Version 19 and imported into Microsoft Excel 2010 where the charts were produced manually. All data were quality checked by two other persons.

122 of these charts were provided in electronic format to each benchmark participant.

Evaluation

All 59 benchmark participants were contacted by phone or email on the average eight months after receiving the charts to give feedback on the benchmarking procedure. In particular, we asked whether the participants considered the information useful and if yes how they could make use of them. Furthermore, we wanted to know if the participants had any comments on improving the benchmarking procedure and the information. Finally, we asked them whether they would take part in this benchmark again. We used open questions because we were not sure about what the CIOs wanted to tell us. The answers in the telephone interviews were recorded on paper and used together with the email answers to extract significant statements and to group them according to recurring themes of similar content. Two persons categorised the free text answers independent from each other, in order to ensure an objective analysis. In case of disagreement they discussed the issues to find a solution. The reason for contacting them with some delay after sending the charts was to give them enough time to fully exploit the information, e.g. use them to justify investments or show deficiencies to the board of directors.

Results

Participation and raw performance indicators

About one-third of the survey participants (59 out of 193) took the offer of having their hospital benchmarked. They were allocated to two reference groups. As Table 2 shows these groups were populated with at least 17 hospitals in the size group "600 to 799 beds" and ranging up to 141 hospitals in the ownership group "public hospitals".

Table 2: Size of the reference groups for hospital size (n=190) and ownership (n=180) and participant groups [1]

	hospital size (n=190)					ownership (n=180)	
	up to 199 beds	200 to 399 beds	400 to 599 beds	600 to 799 beds	800 beds and more	privat	public
percentage of survey participants in reference group	25.2 % (48)	31.6 % (60)	14.2 % (27)	9.0 % (17)	20.0 % (38)	21.7 % (39)	78.3 % (141)
percentage of benchmark participants in reference group	18.8 % (9/48)	35.0 % (21/60)	22.2 % (6/27)	52.9 % (9/17)	36.8 % (14/38)	23.1 % (9/39)	34.0 % (48/141)

As indicators related to the implementation status were measured by Likert scales, the bar charts showed the distance of the benchmarked hospital to those in the reference group who were best. Figures 1 and 2 give examples of these bar charts for the implementation status of the "clinical reminder" function and the "electronic patient record system". In both cases the hospital belonged to the group "having started implementation or providing resources for implementation" and in both cases the best hospitals of this group had implemented the IT-system/function in all clinical units. The frequency diagrams also revealed information about

[1] Only 190 hospitals had given information on their size and 180 hospitals on their ownership.

the positioning of the hospital within the field of hospitals of the same reference group. Figure 1 shows that the hospital was better than the statistical mode (the category with the highest frequency) in the case of the clinical reminder function, whereas in the case of the electronic patient record system the same hospital was average belonging to the group of the mode, i.e. “having started implementation” (Fig. 2).

Other performance indicators related to the position of the chief information officer (CIO) within the organisation (Fig. 3), number of full-time equivalents in the IT-department and services provided by the IT-department and CIO.

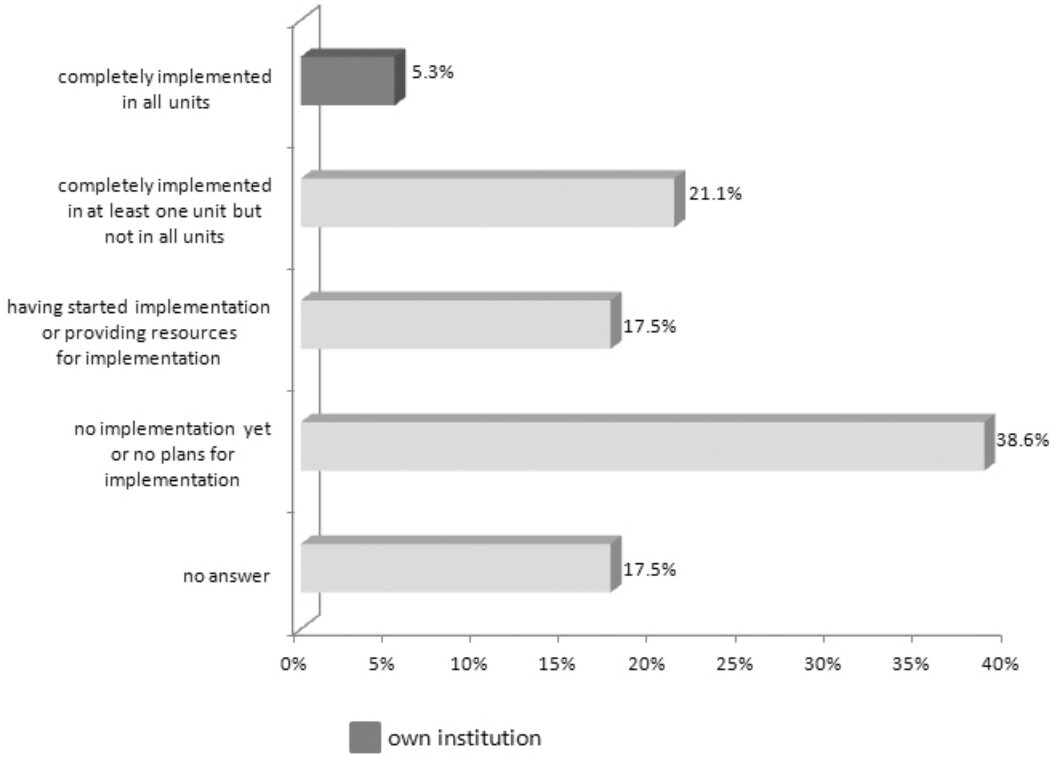

Figure 1: Single indicator frequency view for the implementation status of the function “clinical reminders” in the size reference group “200 to 399 beds” (n= 60).

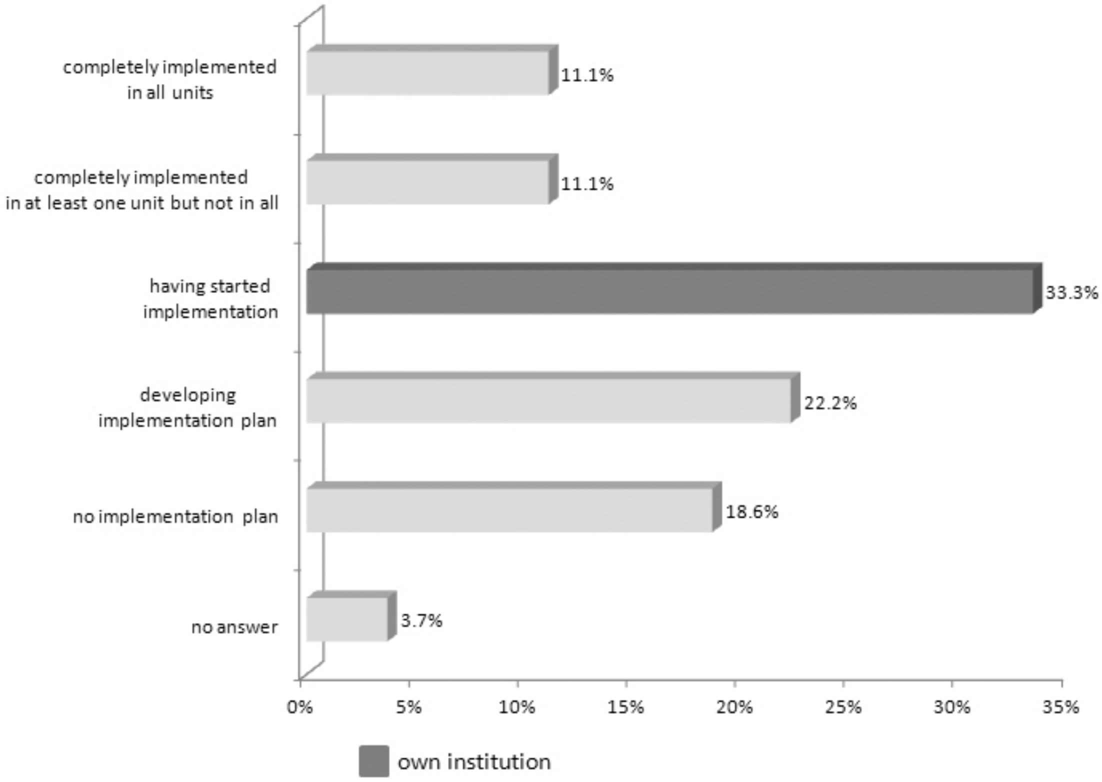

Figure 2: Single indicator frequency view for the implementation status of the electronic patient record (EPR) system in the size reference group 200 to 399 beds (n= 60).

Evaluation

A total of 51 persons from the 59 benchmarking participants (86 %) took part in the evaluation, 18 via email and 33 via telephone interviews. Eight persons could not be contacted neither by mail nor by phone. The large majority of the 51 persons (94,1%) reported that they could make use of the benchmarking information. Three persons (5,9%) said that they either did not have enough time to devote themselves with benchmarking or preferred other indicators (usage of systems instead of availability). The persons who considered the benchmarks beneficial gave a combination of reasons for their opinion (tab. 3). Twenty persons (39,2%) made comments on how to improve the benchmarks. The majority of answers referred to the use of cost indicators. Other suggestions included the use of additional indicators or the provision of more details, guidance and follow-ups and the presentation of the results in a more consolidated manner (tab. 4). Four persons explicitly mentioned and esteemed the scientific and independend approach. Ninety-four percent (94.1%) of the participants who evaluated the benchmark responded that they would enter again.

Table 3: Types of usage of the benchmark results (n=51)

percentage of	type of use (percentage of answers from all answers)

respondents who could make practical use of the benchmark	learn about position in peer group	strategic alignment	discussions with users and executives
94.1 %	48.5%	28.1%	23.4%

Table 4: Comments for improving the benchmarks (n=51)

percentage of respondents who made comments	type of comments (percentage of answers from all answers)			
	use of cost data, e.g. for cost-benefit ratio	Use other indicators in addition and provide more details	provide guidance and have some sort of follow-up	Provide a more consolidated presentation of the results
39.2 %	50.0%	22.7%	18.2%	9.1%

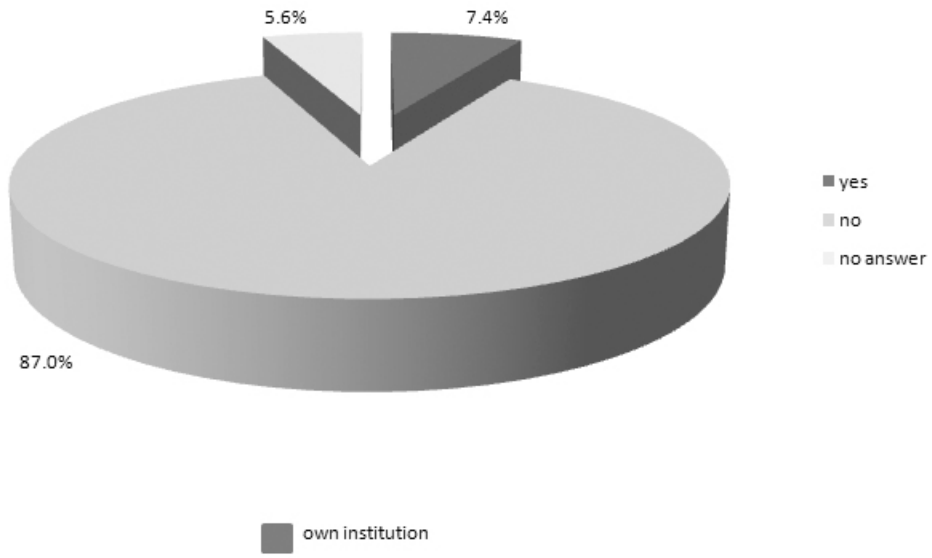

Figure 3: Single indicator frequency view for whether the chief information officer was member of the board of directors in the size reference group 200 to 399 beds (n= 60).

Alternative views

Based on the wish of the participants for a consolidated perspective on the data we sought a solution to combine different types of information visually. In addition to the *single indicator frequency views*, which made use of the raw indicators, we thus developed two alternative views for visualising the implementation status of different IT-systems/functions that aggregated the raw indicators and emphasised particular aspects within the data. In the first type of diagrams, *the multiple indicator distance views*, IT-systems/functions that belonged to the same category were depicted in a web graph together with their degree of implementation. Connecting the values for the degree of implementation yielded a characteristic picture so that the shape of the best within the reference group and that of the own institution could be compared (Fig. 4). As the indicators were scaled as ordinal data discrepancies could be interpreted as distances. This view did not contain any information on frequencies.

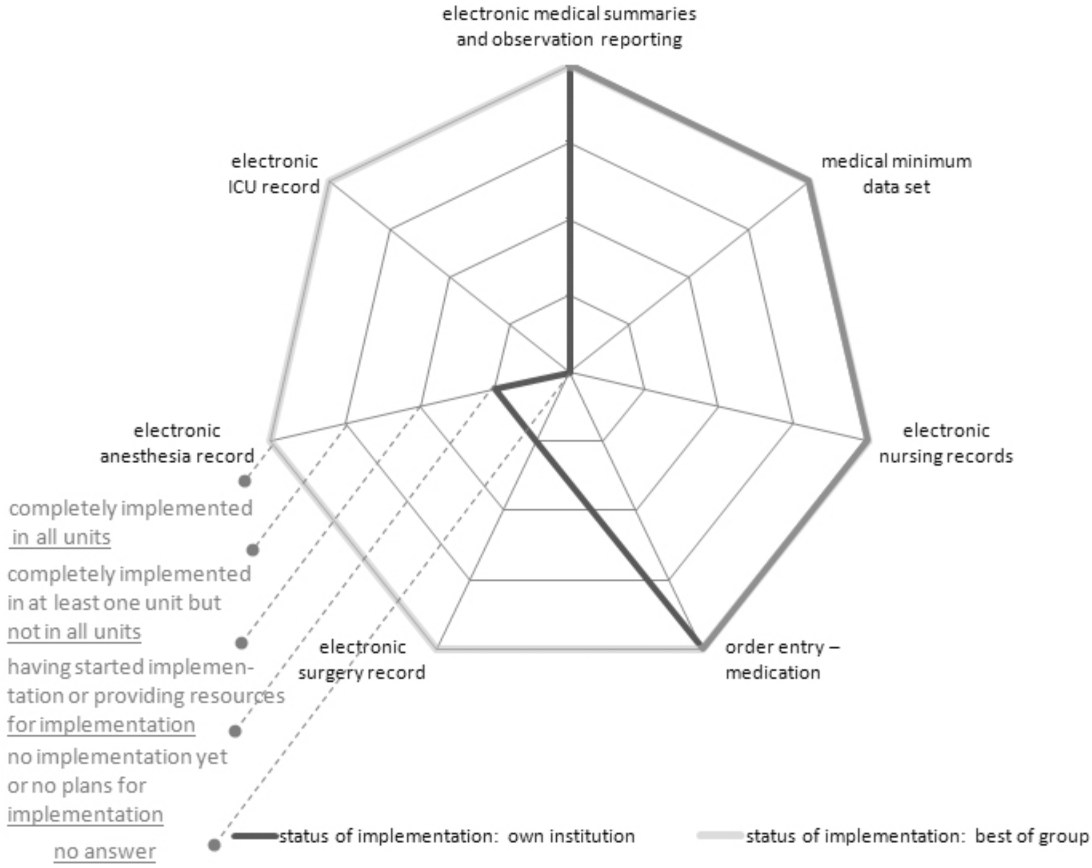

Figure 4: Multiple indicator distance view for IT-systems/functions related to documentation in the size reference group 200 to 399 beds (n= 60).

The second type of diagrams, the *multiple indicator innovation views,* allowed the user to classify the own organisation in terms of its type of innovation (Fig. 5). Similar to the *multiple indicator distance view* a group of IT-systems/functions was targeted. Each system/function was localised in two dimensions: first the implementation status and second the frequency of the specific manifestation of the implementation status in the own organisation. For example, the hospital in Figure 5 had implemented the electronic nursing record “in all units” (x-axis) like 10% of the hospitals (y-axis) in the reference group. By positioning the IT-system/function in the plane, the user could identify to which quadrant the own organisation belonged to with regard to this IT-system/function: a) the lower right corresponded with innovators/early adopters, b) the upper right with an advanced majority, c) the upper left with an unprogressive majority and d) the lower left with laggards or technology grouches. These terms were chosen referring partly to Rogers' *Diffusion of Innovation* theory [33]. If a hospital was very advanced with regard to having implemented a specific system and if only few other hospitals in this group shared the same implementation status this hospital was called an early adopter (lower right). If the hospital had not implemented a specific system and there were more hospitals with a better implementation status then this hospital lagged behind (lower left). The two upper quadrants identified majorities, i.e. an implementation status that was shared by 50% or more. In the upper right the majority was advanced, and in the upper left the majority was rather behind. The hospital in Fig. 5 was an early adopter within its reference group in terms of the electronic nursing record system and the order entry system (medication); it lagged behind in terms of the electronic surgery and anaesthesia record systems.

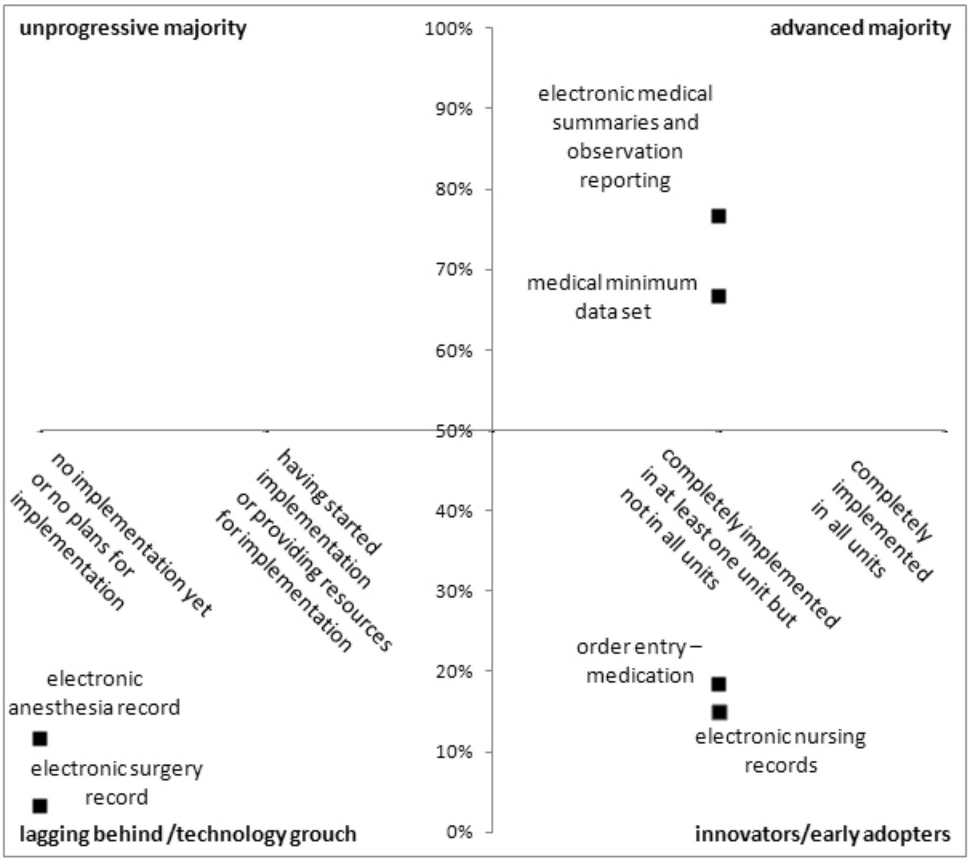

Figure 5: Multiple indicator innovation view for IT-systems/functions related to documentation in the size reference group 200 to 399 beds (n=60).

Discussion

Feasibility

In this study, we could demonstrate that a large number of IT-performance indicators measuring structural features of a healthcare organisation and functional characteristics of the IT-system could be captured using a questionnaire, could be analysed statistically within reference groups and could be visualised in various views. The number of benchmark participants revealed the interest in this procedure and the positive feedback given in the evaluation was encouraging to continue along the way.

Hospitals from all size groups expressed the wish to take part in the benchmarks. This illustrates an interest in getting benchmarked that is independent from hospital size.

Capturing IT-performance indicators in an online survey with CIOs using a standardised and well tested questionnaire helps to fulfil two success criteria: a) data acquisition is comparatively time saving, which is a criterion that Jahn and Winter deemed desirable [27] and b) the chance to receive high quality and meaningful data is great as persons that oversee the IT-landscape of the organisation are the respondents – which is a criterion stipulated by Hübner-Bloder and Ammenwerth [17].

Statistical and scientific approach

The combination of conducting a regular national survey on IT-adoption in healthcare organisations and of benchmarking its participants or at least a subset of them allows a statistical approach to comparing similar organisations. The main advantage is that the size of the reference groups does not depend on the number of benchmarking participants but on the number of survey participants (scalability). Furthermore, reference groups can be established on the ground of statistical analyses that give appropriate information for building them. The feasibility of the benchmarking and the intention of the benchmark participants to enter again constitute a solid ground for its repeatability. The evaluation results show that the objective and scientific approach was appreciated, which confirms and corroborates the initial goal of providing independent results.

Repeatability and international use

There is good evidence on the repeatability of the benchmark as results from a current call for participation indicate. A total of 182 hospitals out of 260 participants of the 2013 survey expressed their interest to take part in the benchmark. Forty participants of the 180 hospitals had been already benchmarked two years ago. The current procedure includes dedicated process indicators in combination with structural and functional performance indicators.

The IT-benchmarking procedure we are proposing is also suitable for other countries in our view. The standardised questionnaire has already been utilized in surveys outside Germany, i.e. in Austria in 2007 and 2009 [30, 34] and in The Netherlands in 2011 [35] and served to compare the adoption of health IT in two countries.

Performance indicators and visualisation

We utilised a very large number of performance indicators, which resulted in a large number of *single indicator frequency views* per hospital. These views were not only very detailed with regard to the many raw indicators but also with regard to providing frequency information derived from the reference group. Based on suggestions made by participants we developed more aggregated views in which similar indicators were grouped: one view focuses on the distance to the best of the group (*multiple indicator distance view*), and the other on the identification of systems and functions in which the participant belongs to the leading edge and those where they do not (*multiple indicator innovation view).* These views will have to be fully evaluated in the next series of benchmarks.

The performance indicators used in our trial primarily embrace structural features of the organisation and functional characteristics of the IT-systems. Knowing that the structure is not the only constituent of quality [36] it also becomes clear that other features need to be measured – first and foremost the degree with which IT supports and optimises clinical processes and eventually how IT contributes to improving clinical outcomes.

In order for indicators and views to be actionable in very practical terms, the challenge will be to design them carrying meaningful and comprehensive messages while still keeping them simple enough.

Guidance

Measuring performance indicators and benchmarking institutions serves the ultimate goal of knowing what to do in order to become better. Our benchmarks yield exact details about the *where*, i.e. technical, human and financial resources, in which there is the greatest need for action. Statistical benchmarks, however, also allow for advice on the *how.* The multiple regression analyses employed to constituting the reference groups via context factors ("hard" factors) gave additional information on "soft" factors, i.e. circumstances that can be changed in a given time. Those hospitals that had implemented the largest number of IT-systems had *IT-departments*, were *reference* customers *(priority customer)*, i.e. entertained a good relationship with their main IT-vendor, and had a *strategic IT-plan* [32]. Drawing on these results the global advice for hospitals that want to change is to check their organisation in terms of these features. Mutual exchange between the IT-department of the organisation and the IT-vendor lays the foundation of an innovation partnership: New products are made available easily to the hospital, and can be tested and adjusted according to the customer's input. If there is a strategic IT-plan implementing new systems does not happen ad hoc but is embedded into a portfolio of new projects and into a clear understanding of how new systems contribute to reaching overall strategic goals of the organisation. It also may be assumed that IT-investments can be pushed through more effectively in the case of a strategic IT-plan.

Limitations

The main limitation of this benchmark is its focus on structure and function. We are, therefore, currently developing indicators for the quality of IT accompanying clinical processes. Based on this additional information we will measure the structural and workflow parameters together. Although asking CIOs warrants high quality data on technical issues CIOs and other members of the IT-staff can give no evidence on how IT is perceived by clinicians and if they value its contribution to patient care. More comprehensive benchmarks will have to include their perspective as well, in particular when it comes to scrutinising clinical information and processes. Their view would definitely enhance the credibility and validity of the information base.

Statistical benchmarks of the type we are proposing will probably always have problems taking into account the idiosyncrasies of individual organisations. If a benchmark needs to achieve an in-depth analysis of differences between the peers then other types of benchmarks seem more appropriate, i.e. with a small number of participants and semi-structured interviews. We therefore argue the case for multiple approaches to benchmarking depending on the goals, the environment and the resources available.

Conclusion

The proposed IT-benchmarking procedure meets the requirements of independency, scalability and repeatability, and adds a new approach to existing procedures. However, processual performance indicators need to complement the structural indicators. Furthermore the various views will have to undergo rigorous testing and new views will have to be designed. More multivariate statistical analyses should be employed to identify further combinations of factors that are associated with IT-performance and allow a systematic and evidence based improvement of current practice. If an organisation, however, wishes to change its structure this benchmark already yields valuable information on detailed targets, e.g. implementation status of particular IT-systems/functions, and on global measures, e.g. establishing a strategic IT-plan.

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Beitrag 2: IT Benchmarking of Clinical Workflows: Concept, Implementation, and Evaluation

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Tabelle 3. Überblick Beitrag 2

IT-Benchmarking of Clinical Workflows: Concept, Implementation, and Evaluation

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Abstract. Due to the emerging evidence of health IT as opportunity and risk for clinical workflows, health IT must undergo a continuous measurement of its efficacy and efficiency. IT-benchmarks are a proven means for providing this information. The aim of this study was to enhance the methodology of an existing benchmarking procedure by including, in particular, new indicators of clinical workflows and by proposing new types of visualisation. Drawing on the concept of information logistics, we propose four workflow descriptors that were applied to four clinical processes. General and specific indicators were derived from these descriptors and processes. 199 chief information officers (CIOs) took part in the benchmarking. These hospitals were assigned to reference groups of a similar size and ownership from a total of 259 hospitals. Stepwise and comprehensive feedback was given to the CIOs. Most participants who evaluated the benchmark rated the procedure as very good, good, or rather good (98.4%). Benchmark information was used by CIOs for getting a general overview, advancing IT, preparing negotiations with board members, and arguing for a new IT project.

Keywords: IT-benchmarking, clinical processes, information logistics, information management, visualisation of indicators

1. Introduction

Health IT (HIT) has become a production factor that is starting to demonstrate its contribution to the health care value chain [1-4]. Due to its potential for becoming part of the care processes as well as due to the risk for endangering the clinical workflows [5], continuous measurements of the efficacy and performance of health IT are imperative and a part of good health care leadership [6]. Planning, monitoring, and aligning IT resources have to take place at all levels: the strategic, tactical, and operational levels [7-8]. IT-benchmarks are a recognised means for delivering insight into the structure, processes, and outcomes of an organisation [9]. It provides facts for chief information officers (CIO), health care leaders, and other decision makers to govern change [10]. IT-benchmarking thereby embraces a full toolset for measuring performance in small groups of peer organisations (in-depth benchmarking) as well as in large reference groups (statistical benchmarking). In 2011, we conducted an independent, publicly funded statistical IT-benchmark of 59 German hospitals (2011 IT-Benchmarking Healthcare) based on the national surveys of the IT-Report Gesundheitswesen [11]. The hospitals could be assigned to sufficiently large reference groups selected on the basis of factors that were derived from regression analyses [12].

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We showed that the 61 variables represented the implementation status of the structural and functional IT features, IT resources, CIO satisfaction, and context factors rather well that were good predictors for advanced HIT systems [13]. The benchmark demonstrated the feasibility of a scalable and repeatable procedure for continuous measurements and its utility. However, the indicators employed did not cover the features of clinical workflows, as one of the most important yardsticks of meaningful health IT, albeit difficult to capture [14]. We, therefore, aimed at enhancing the existing IT-benchmarking toolset and specifically asked:
1) How can the IT support of clinical workflows be statistically benchmarked?
2) How can the indicators be properly visualised?
3) How do the participating CIOs evaluate the benchmark?

2. Methods

2.1 Initial Situation: 2011 IT-Benchmarking Healthcare Evaluation Results

Advancing the existing procedure of the 2011 IT-Benchmarking Healthcare [11] based on two strands: the results of the 2011 evaluation and the goal to measure the IT support of clinical processes. The evaluation had shown that the large majority of participating CIOs had found the benchmark to be very useful. Improvements were suggested with regard to the inclusion of additional indicators, e.g. costs, follow-ups, and more consolidated presentation of results [11].

2.2 IT-Benchmarking Healthcare 2013

2.2.1 Information Logistics - Concept for Measuring the IT Support of Clinical Workflows

We used the concept of information logistics as the underlying construct for measuring the IT support of clinical workflows, i.e. IT efficacy on clinical processes. Pursuant to this concept "the right information" needs to be provided in the "right amount and quality", at the "right time", to the "right place" [15-16]. In order to summarise these demands, they were translated into measurable workflow descriptors (Tab. 1) after in-depth discussions with seven health IT experts and after analysing the relevant literature [8,17-19]. Benchmark variables, i.e. raw indicators, should be mapped to these four workflow descriptors, namely the availability of *data and information* along the processes, availability of process relevant *functions,* depth of *integration* and *distribution* of data and information via mobile devices and exchange platforms.

Table 1: Information logistics' demands [15-16] predominantly associated with workflow descriptors

"right information"	*data and information, functions*
"right amount"	*data and information, functions, integration*
"right quality"	*data and information, functions*
"right time"	*functions, integration, distribution*
"right place"	*integration, distribution*

Measuring the degree of IT support of clinical workflows required representative clinical processes in order to operationalise the clinical workflow concept. These processes had to be IT demanding and sufficiently complex with regard to interdisciplinarity or to spanning departments or settings. Based on these criteria, we chose ward rounds, pre-surgery (from ward to theatre), and post-surgery (from theatre to intensive care unit) processes and discharge to represent clinical workflows in acute care hospitals.

2.2.2 From Raw Indicators to Workflow Indicators

The 2013 online questionnaire consisted of 44 main questions, which constituted 86 raw indicators (RI) that were derived from the combination of workflow descriptors and clinical processes plus additional information on factors influencing IT in a hospital. They covered the four main topics *general IT structure and functions (38 RI)*, *specific IT support of the four selected clinical processes (18 RI)*, *IT governance (23 RI),* and *context factors (7 RI)* including hospital demographics. These questions were similar to the 2011 survey instrument with regard to *IT structure and functions* and *context factors*. The attributes of the raw indicators were given points: A maximum of ten points could be achieved per clinical process (process score) with 2.5 points per workflow descriptor in each process.

2.2.3 Additional Performance Indicators

In accordance with the 2011 evaluation results we included new performance indicators, i.e. COBIT 4.1. IT governance maturity items [20] and various cost items in order to measure efficiency. The COBIT process items embraced planning, procurement, implementation, deployment, support, and evaluation processes. Similar to process scores, IT governance attributes were assigned points, which were then added to an IT governance sum score. Information on the costs covered the total costs and the percentage of costs for staff, hard- and software and services. Cost indicators were computed as costs relative to the number of beds and full-time equivalent IT staff. Similarly, service ratios were calculated as beds, users, physicians, and nurses per full-time equivalent IT staff.

2.2.4 Dataset

A total of 1,317 chief information officers and other leading IT managers, who were responsible for 1,675 hospitals, were included in the survey, which took place from February to June 2013. The remaining 331 German hospitals either did not employ a person in charge of IT or did not want to take part. All the survey participants received the offer to take part in the benchmark. Out of these 1,317 persons, 259 answered the questionnaire (19.7% response rate). These 259 hospitals represented organisations of all sizes, ownerships, and from all states within Germany. Additional information on the 259 participating hospitals, e.g. clinical staff, was retrieved from publicly available quality reports (Social Security Code Five §137). All data were analysed using IBM SPSS Version 21.

2.2.5 Selecting Reference Groups

In accordance with the 2011 IT-Benchmarking Healthcare [11] and with results from regression analyses [12] hospital size and ownership were chosen as factors to build the reference groups. Hospital size was expressed as the number of beds clustered in five classes. Ownership distinguished between private and non-private hospitals. Not all hospitals that participated in the benchmarking had surgeries and intensive care units. These hospitals were benchmarked based on the scores of the ward rounds and discharge process only.

2.2.6 Visualising the Benchmarking Results

Benchmark results were presented in two groups of views, “single indicator” and “multiple indicator” views. Raw indicators, i.e. the answers of the responding hospital to a question were shown as frequency views [11] and performance bars [21], which belonged to the “single indicator” views. Raw indicators were also grouped according to headings such as documentation, provider order entry and decision support. These groups were depicted in “multiple indicator” views, i.e. distance views, which provided a web view, and innovation views, which showed a 2x2 matrix for sorting hospitals into the Roger’s classes of adopters [11, 22]. Accumulated indicators, i.e. the workflow descriptors, were presented in score views, which resembled performance bars. The intention of these views was to increase awareness, improve perception, and increase acceptance [23]. All the views were generated in a semi-automated manner using Microsoft Excel.

2.2.7 Evaluation

All the benchmarking participants were asked to evaluate the benchmark in terms of use of the results, comments on improvement, and intention to participate again. The questions were supplemented with items on the comprehensibility and utility of the indicators, their visualisation, and the benchmarking in general. The evaluation took place from the end of August to the end of September 2013.

3. Results

3.1 Participation, Reference Groups, and Feedback to the Participants

Out of the 259 CIOs that answered the questionnaire, a total of 199 CIOs participated in the 2013 benchmarking. Compared to 2011, this meant an increase of 140 hospitals, whereby 40 hospitals took part again. This corresponded to a net increase of 269% and a repetition rate of 68%. 67 CIOs evaluated the benchmarks (34% response rate). Table 2 shows the size of the reference groups.

Table 2: Reference groups

		benchmark participants	size of reference groups
ownership	Non private hospitals	161	202
	Private hospitals	38	57
size	Up to 199 beds	59	81
	200 – 399 beds	55	77
	400 – 599 beds	36	43
	600 – 799 beds	20	22
	800 and more beds	29	36

Feedback to the benchmark participants was given stepwise. Immediate feedback with 3 indicators was given one month after closing the survey, a short version of the individual results containing 50 indicators and 16 tables and diagrams was sent as paper document by mail after three months and a final report of 106 pages (PDF document) with 117 indicators and 169 tables and diagrams was made available by e-mail after three and a half months.

3.2 Measuring and Visualising IT support of Clinical Processes

IT support of the clinical processes was represented in a hierarchical way as recommended in the literature [24]. At the top level, the degree of IT support expressed as a sum score was shown for each clinical process as a bar in comparison to the median of the respective reference group (Fig. 1). A similar diagram showed the scores for the four workflow descriptors.

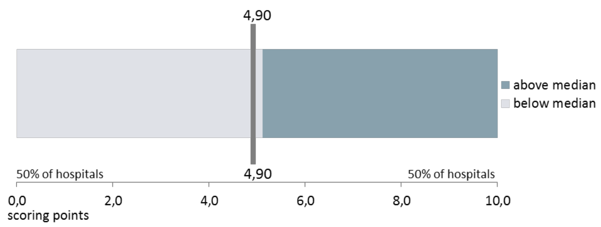

Figure 1: Sum score view *IT support of patient discharge* – individual score in comparison to the median of the reference group

These views were then broken down to the level of raw indicators, which were depicted as performance bars (Fig. 2) that contained information on the implementation status of the individual hospital and the distribution of status groups, i.e. the percentage of reference hospitals within these groups.

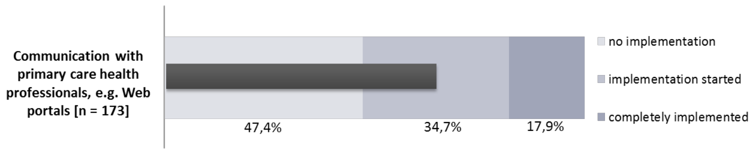

Figure 2: Performance bar of raw indicator *Implementation status of web portal for e.g. discharge letters* – individual score as black bar against the frequency distribution in the reference group

In addition to the sum scores and the performance bars, which showed the performance of a raw indicator, participants could also see their own judgement about how well IT supported the clinical processes in relation to the reference group (Fig 3).

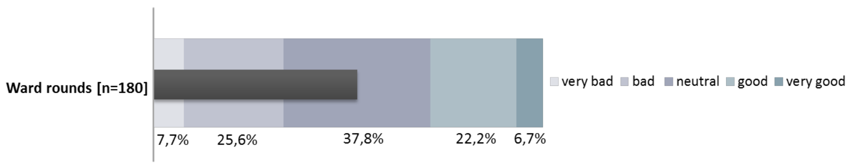

Figure 3: Performance bar *Subjective judgement on quality of IT support of ward rounds* against the frequency distribution in the reference group

Raw indicators were clustered in innovation views, which belonged to the type of "multiple indicator" views and should show the degree of innovation of this hospital with regard to a group of raw indicators (Fig. 4). The degree of innovation was defined by the combination of information on the implementation status of these IT functions in that hospital and the percentage of hospitals in these implementation groups. There were four stages of innovation: innovators, early majority, late majority, and laggards, which resembled the innovation classes of Roger's [22].

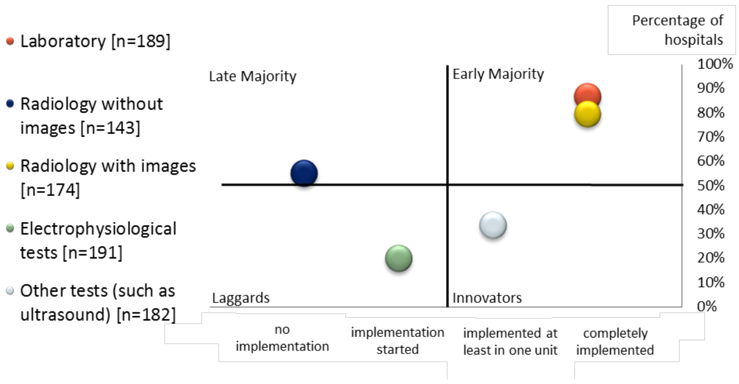

Figure 4: Innovation view *Order entry system* for various tests. Buttons represent implementation status of own hospitals (x-axis) and percentage of hospitals in same status group (y-axis)

3.3 Measuring and Visualising IT Governance and Cost Indicators

The benchmark results of IT governance were shown in comparison to the reference group as performance bars or in comparison to the best of the reference group as web diagrams (Fig. 5). Cost indicators and service ratios were summarised in tables together with the respective medians of the reference groups and their size.

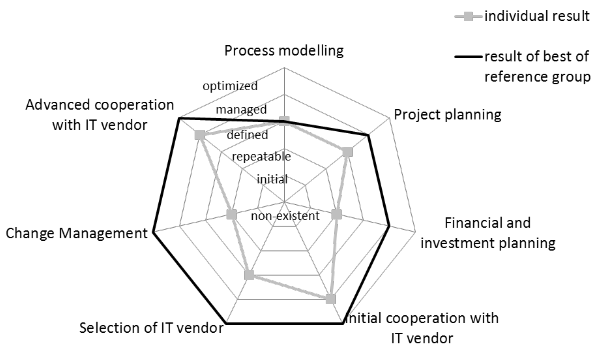

Figure 5: Distance view *IT governance – process maturity planning, procurement, and implementation*

3.4 Evaluation

The overall evaluation of the 2013 benchmark resulted in a general positive judgement ("very good" or "good") of more than three quarters (77.4%, n = 63) of the evaluating participants. Nearly all of them (98.4%) evaluated the benchmark as at least "rather good". Moreover, 90.6% (n = 64) stated that they would participate again. The preferred average time between benchmarks was 2 years (median, n = 65). The evaluation of the different types of visualisation (Tab. 3) demonstrated that at least two third of the participants found the diagrams comprehensible or very comprehensible.

Table 3: Comprehensibility of the different types of visualisation and scores

types of visualisation	very comprehensible	com-prehensible	less com-prehensible	not com-prehensible at all
performance bars [n=66]	37.9%	53.0%	7.6%	1.5%
frequency views [n=65]	35.4%	58.5%	4.6%	1.5%
distance views [n=67]	22.4%	55.2%	16.4%	6.0%
innovation views [n=66]	22.7%	45.5%	28.8%	3.0%
sum scores for				
clinical processes [n=66]	16.7%	63.6%	18.2%	1.5%
IT governance [n=64]	15.6%	62.5%	20.3%	1.6%

The less consolidated the diagrams were the better they were regarded, i.e. at least "comprehensible" for the single indicators (93.9% frequency views, 90.9% performance bars) versus for the multiple indicators (77.6% distance views, 68.2% innovation views). Approximately 80% of the participants evaluated the sum scores for the clinical processes and for IT governance positive. In addition, the utility of *service ratios* and *IT costs* was rated resulting in high agreement of the helpfulness of these indicators (Tab. 4).

Table 4: Utility of additional indicators

indicators	very helpful	helpful	less helpful	not all helpful
service ratios [n=64]	29.7%	56.2%	12.5%	1.6%
IT costs [n=64]	34.4%	54.7%	10.9%	0.0%

Reasons for participating in the benchmark and for using the results (n = 65) encompassed the "general overview of the IT in the hospital" (92.3%), "approach for further developing the IT in the hospital" (75.4%), "foundation for discussions and negotiations with board members" (55.4%), and "basis for arguing in favour of new IT projects" (46.2%).

4. Discussion

In 2013, IT-Benchmarking Healthcare could be repeated in an enhanced version that included the measurement of supporting clinical processes with IT and of governing IT in a systematic manner. It also contained more sophisticated types of indicator visualisation. Participation could be more than tripled. 68% of the hospitals that participated in 2011 also took part in 2013. Ample feedback could be given to the participants. An overall and detailed evaluation yielded positive and highly encouraging results. We could thus validate the feasibility, high interest, and usefulness of this approach plus demonstrate the utility of the new indicators.

Measuring IT performance with regard to clinical processes has recently gained high attention in the Meaningful Use programme in the United States as Stage 2 criteria directly targeting clinical processes [19]. Although there is some overlap of applications, e.g. tracking medication from order to administration, we pursued a different approach that emphasised the role of a sample of clinical processes and the concept of information logistics. We are not the first to benchmark workflow support [e.g. 6, 14, 25], our work particularly contributes to making clinical process support measurable in a statistical benchmarking procedure. This was achieved by incorporating a hierarchy of indicators from sum scores to raw indicators to represent workflow quality. These indicators will become part of the survey instrument, which had been used in a highly consistent and standardised manner over many years [26].

We offered a wide range of different visualisation types from single indicator views to highly consolidated forms of presenting the data. In contrast to the recommendations of the 2011 benchmark, more compact ways of depicting the results seemed less desirable pursuant to our 2013 evaluation results. Frequency views and performance bars received the best marks and thus will be certainly retained in the next benchmarks.

Although cost indicators were regarded as helpful it was not easy to obtain good data from a sufficiently large group of respondents. This is probably a field of indicators where statistical benchmarking reaches its limits. Presenting the results of IT governance maturity received a positive feedback from the participants and will, therefore, be integrated in further benchmarks. Our measures were compliant to COBIT 4.1 and will have to be migrated to the COBIT 5.0 Process Capability Model [20].

There are some limitations in our approach that mainly relate to measuring clinical workflow support at the level of CIOs and IT leaders. They can give the most reliable information on technical features but without being able to appraise the use and usefulness. We are, therefore, currently conducting a survey with similar content that is addressed to clinicians. It is geared to the actual use and clinical user satisfaction. Usability and human computer interaction issues could be included in future studies. The evaluation of our benchmark proved to be an extremely helpful instrument for shaping the next version of the benchmark. Having said that, its results should not be over-interpreted due to the rather moderate response rate. This may have been caused by a small time window, during which the evaluation took place.

There are several open issues of this study. Performance over time has to be analysed and presented to those participants who had taken part for the second time. The sum scores for clinical processes and workflow descriptors need to be further tested for consistency and should be validated against external measures.

In conclusion, there is evidence from the number of participants, the increase in their number since the last benchmark, the number of second time participants and – with some caution – the evaluation results that this benchmark has the potential to provide the continuous measurements stipulated by benchmarking theory.

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Beitrag 3: Developing a Workflow Composite Score to Measure Clinical Information Logistics

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Tabelle 4. Überblick Beitrag 3

Developing a Workflow Composite Score to Measure Clinical Information Logistics

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Keywords: clinical workflows, IT support, clinical information logistics, workflow management, composite score, validation

Abstract

Background: Availability and usage of individual IT applications have been studied intensively in the past years. Recently, IT support of clinical processes is attaining increasing attention. The underlying construct that describes the IT support of clinical workflows is clinical information logistics. This construct needs to be better understood, operationalised and measured.

Objectives: It is therefore the aim of this study to propose and develop a workflow composite score (WCS) for measuring clinical information logistics and to examine its quality based on reliability and validity analyses.

Methods: We largely followed the procedural model of MacKenzie and colleagues (2011) for defining and conceptualising the construct domain, for developing the measurement instrument, assessing the content validity, pretesting the instrument, specifying the model, capturing the data and computing the WCS and testing the reliability and validity.

Results: *Clinical information logistics* was decomposed into the descriptors *data and information, function, integration* and *distribution*, which embraced the framework validated by an analysis of the international literature. This framework was refined selecting representative clinical processes. We chose ward rounds, pre- and post-surgery processes and discharge as sample processes that served as concrete instances for the measurements. They are sufficiently complex, represent core clinical processes and involve different professions, departments and settings. The score was computed on the basis of data from 183 hospitals of different size, ownership, location and teaching status. Testing the reliability and validity yielded encouraging results: the reliability was high with $r_{split\text{-}half} = 0.89$, the WCS discriminated between groups; the WCS correlated significantly and moderately with two EHR models and the WCS received good evaluation results by a sample of chief information officers (n=67). These findings suggest the further utilisation of the WCS.

Conclusion: As the WCS does not assume ideal workflows as a gold standard but measures IT support of clinical workflows according to validated descriptors a high portability of the WCS to other hospitals in other countries is very likely. The WCS will contribute to a better understanding of the construct *clinical information logistics*.

1. Introduction

Studies in health IT adoption, usage and impact often focus on structural features of quality, i.e. the existence of a certain IT system with dedicated functions. These features may serve as dependent or independent variable. However, structure is only one dimension of quality [1], a notion that has been widely accepted throughout health care. The other dimensions, i.e. process quality and outcome quality, are now coming increasingly into the view of evaluation studies [2, 3]. The questions addressed are: how can health IT contribute to the quality of clinical processes and to care outcomes. Before being able to answer these questions properly the type and manner of IT supporting processes and outcomes has to be clarified. With regard to processes the question then narrows down to how can IT support of clinical workflows be measured.
Investigating workflow support widens the scope from IT support of individual tasks performed by a single person to IT support of entire care processes spanning teams, units, departments and institutions1. In this light, it is not only the type and number of IT systems installed, let alone individual applications, but a chain of integrated and interoperable systems [4] that accompany the clinical workflows. Integration and interoperability hereby do not only refer to the technology used but also to the data and the information that is stored in the various heterogeneous systems and that steers the processes in routine care as well as in unexpected events. Process-aware information systems in health care therefore strongly depend on the access to the data sources [5, 6]. Integration and interoperability seek to bring together data, information and functions in one place and are an important prerequisite for mobility which furthermore aims at distributing data, information and functions to different places [7].

The notion of information transported from one node to another by information systems is captured by the idea of information logistics, which was first proposed by [8] and later utilised to describe process phenomena [9]. It is a construct that is defined and assessed by the degree with which the user obtains exactly and on time the information needed for arriving at the right decision. In the ideal case, information logistics is built from the interaction of different constituents. It thus can draw on other concepts such as IT automation [10]. IT sophistication [11, 12], system, information and service quality [2], which overlap with the idea of information logistics and which can stimulate its operationalisation. Consequently, IT support of clinical processes and the underlying concept of information logistics demand a measure that reflects its different constituents and amalgamates them into a composite score.

[1] "It has been shown that HIT produces strong externalities, and it is highly plausible that a significant portion of the value of HIT is not captured by the entity that makes the investment. The benefit from information exchange between hospitals and practices can be significant" [17].

Such a workflow composite score (WCS) could serve different purposes in empirical studies – both as independent and dependent variable, for example for showing the effect of IT workflow support on care quality and efficiency or for identifying factors that foster health IT supporting clinical processes. As composite score it would help aggregating information and allowing comparisons over time and benchmarks between institutions and countries [13, 14, 15, 16]. Although composite scores are common in condensing and measuring IT related characteristics in health care [e.g. 2, 10, 16], there is no composite score to our knowledge that specialises on clinical workflows, operationalises clinical information logistics and makes the construct measurable on a large scale.

It is therefore the overall aim of this study to propose and develop a workflow composite score (WCS) and to examine its quality based on reliability and validity measures. In detail, this study seeks to answer the following questions:

1) What is a valid framework for the standardised measurement of IT support of clinical workflows that can lead to the construction of a workflow composite score (WCS) and what is a suitable WCS inventory, in the sense of a useful structure and useful IT related features (short: *features*) based on this framework?
2) How reliable and valid is this workflow composite score?

2. Materials and Methods

2.1 Overview

In order to construct a workflow composite score we chose a top down approach that is largely orientated on the procedure of MacKenzie and colleagues [18] for building valid constructs. MacKenzie's procedure resembles other methods for constructing scales and scores [13], but differs from them with regard to extracting dimensions or subdimensions. Table 1 shows the individual steps of this procedure that were applied in this specific context. The steps deviate from the original procedure with regard to the rank order of the pretest, which we performed before specifying the final model. We included a separate step for examining the reliability and omitted the last step of the MacKenzie process, i.e. the development of norms for the scale, because this would have required additional work that is independent from constructing and examining the score.

Table 1: Steps undertaken to develop the WCS adapted from MacKenzie and colleagues [18]

Steps of the WCS development	Related questions	Methods applied
(1) Conceptualisation and definition	- What are the main attributes of the construct domain? - How does this construct differ from other constructs? - What sub-dimensions or descriptors[2] belong to the construct domain? - Do these descriptors belong to other constructs as well?	- Literature research - Expert group discussions - Definition of a framework of descriptors based on the literature and discussions - Comparison between the construct domain and other constructs with regard to descriptors
(2) Development of the inventory[3]	- How can these descriptors be translated into an appropriate inventory?	- Operationalisation of the descriptors, i.e. construction of features per descriptor - Definition of the scale per question
(3) Assessment of the content validity	- Do the features capture all relevant attributes of the construct and the descriptors of the construct (completeness)?	- Expert group discussions
(4) Pretest	- Are the questions of the inventory understandable (comprehensibility)? - Is the use of the inventory practicable (feasibility)?	- Pretest with selected users
(5) Model specification	- What are the weights of the descriptors with regard to the construct domain? - What are the weights of features with regard to the descriptors and the construct domain?	- Normalisation - Computation of the feature weights
(6) Data capture and score computation	- How is the WCS distributed and what are related parameters of the distribution?	- Data capture using the WCS inventory - Computation of the WCS for the sample, subsamples and the statistical units

[2] We decided to use the term descriptor instead of dimension or sub-dimension in order to make clear that these descriptors were not derived from empirical procedures such as factor analysis and related statistical methods but were extracted from the literature.

[3] We use the term „inventory" in accordance with the psychometric literature to describe a list of questions (e.g. in a questionnaire) that measure the skills and behaviour of the subject, here the IT systems involved in *clinical information logistics*.

(7) Examination of the WCS reliability	- How reliable is the WCS?	- Computation of the split-half reliability
(8) Examination of the WCS validity	- How valid is the WCS?	- Computation of the scale validity - Computation of the validity with internal and external criteria - Evaluation of the WCS by users of the score

2.2 Definition and Conceptualisation (Step 1)

An in-depth literature review was carried out to find standardised instruments that measure IT usage along the clinical processes. In both cases the literature was searched in the databases Pubmed, Medline, ACM and AISeL. We searched for articles in the timespan 2000 until 2013 and combined one or more keywords that described the technical field of interest (e.g. EMR system) and one or more terms that related to relevant methods (e.g. inventory, composite score or validity). The following keywords were used: *hospital information system, clinical information system, health information system, EMR/EHR system, inventory, questionnaire, validity, reliability, evaluation, composite score, composite index, workflow, process, information logistic, information management*.

As we chose only studies that provided full information on the questions of the measurement instrument, the review resulted in five studies. The constructs were *information technology sophistication*, *hospital information system quality*, *clinical information technology capability*, *meaningful use* and *level of eHealth*. These constructs were broken down into several crucial attributes and were associated to various workflows (see table A1 of the electronic appendix).

In conjunction with the literature review, experts were asked to define the crucial attributes of the construct domain. Two chief information officers (CIO) of hospitals, one clinician and four medical and health informatics scientists were involved in these group discussions (see table A2 of the electronic appendix).

The target construct underlying the literature study and the expert group discussions was *clinical information logistics* in the sense of potential clinical workflow support through information technology. It embraces the demand for „right information“, „right amount“, „right quality“, „right time“ and „right place“ [8]. The construct domain was explored with regard to functions, data, information and knowledge, integration and interoperability, mobility and external availability as well as other potential attributes of the domain. *Clinical information logistics* was compared with other constructs describing IT behaviour, i.e. performance, and IT skills, i.e. interoperability, in a general meaning.

The literature review and the group discussions led to the recommendation of the experts to describe the construct from the perspective of

- the *data and information* that are required to perform the tasks in the selected workflows,

- the *functions* and applications providing and processing these *data and information*,
- the level of *integration* and the capacity of interoperability among these functions and applications,
- the ability to disseminate (*distribution*) the *data and information* to different points of care and to health care professionals outside the own institution.

2.3 Development of the inventory (Step 2)

Step 1 resulted in a framework that was utilised to develop the structure and the content of the inventory[4]. This framework embraced the following workflow descriptors. These are availability of *data and information* along the workflows, availability of workflow relevant *functions* and applications, depth of *integration* and skill for interoperability and capacity of data and information *distribution* via mobile devices and exchange platforms.

This framework was further refined with regard to specific clinical processes that are representative for patient care and that fulfil the necessary requirements for measuring the status of *clinical information logistics* in an institution. These requirements were: The process must belong to the core processes of health care organisations. It must be sufficiently complex. It must either span professions, departments or institutions/settings [19]. We chose the following sample processes that met these criteria: 1) ward rounds (spanning professions), 2) pre-surgery process (from ward to theatre: spanning departments), 3) post-surgery process (from theatre to intensive care unit or normal ward: spanning departments) and 4) discharge (spanning institutions/settings). They may not be standardised across hospitals but they definitely share similar patterns of activities in many hospitals. Workflow descriptors and workflows[5] were combined in a 16 cell matrix which constituted the refined framework (Fig. 1) for operationalising the construct *clinical information logistics*.

[4] The results of Step 1 are described briefly in the Materials and Methods chapter and in a way to make the further steps plausible. The full results are presented in the Results chapter.

[5] In the following we speak only about clinical workflows not about process to express the linkage between the workflows and its descriptors.

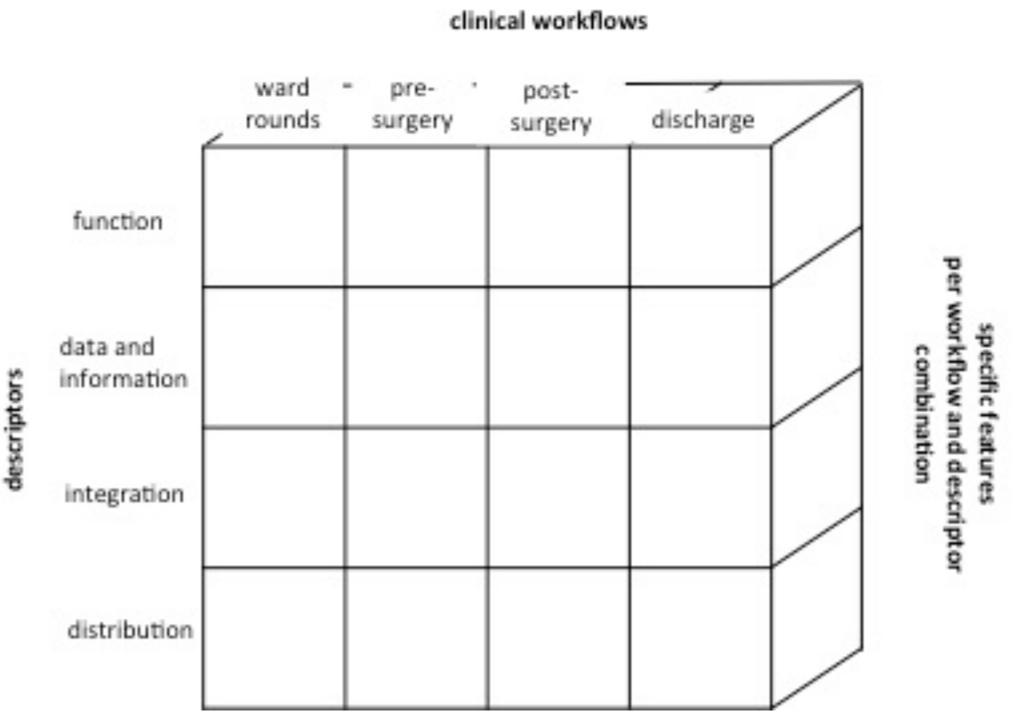

Figure 1: Refined framework (16 cell matrix) for operationalising the construct

Features of the specific descriptor-workflow-combinations were assigned to each cell and related closed questions were developed. In some cases these questions embraced several features as question categories. For example the question "Which patient data are available on mobile devices?" captures several features (i.e. patient demographics, results (text), results (images), results (electrophysiology), kardex with medication and vital signs, warnings, orders). In other cases one question captured only one feature, e.g. "What is the degree of WiFi implementation in your institution?". The questions and the features were based on existing instruments [20, 21, 22]. As neither the workflows for themselves nor the workflow descriptors for themselves were independent from each other, the related features could be assigned to several cells. This set of questions was supplemented by additional questions covering subjective measures on the quality of IT workflow support and hospital demographics.

2.4 Assessment of the content validity (Step 3)

Content validity was examined in two phases. In a first round, the framework of workflow descriptors was assessed by a group of experts who searched the relevant literature (result from step 1) for sets of IT related features and checked independently from each other whether these features could be assigned to the workflow descriptors. In a second round, the questions and the features captured by the questions in the inventory were evaluated regarding their relevance and completeness by a mixed group of 10 experts (Tab. 3). This assessment was based on the refined framework of the 16-cell-matrix (Fig. 1). During this process, adaptations and changes were made to the questions, their features and their allocation to the descriptor – workflow - combinations.

2.5 Pretest (Step 4)

Once the questions were stable (result of Step 3) the inventory was implemented in an electronic form using Unipark online survey tool and was given to a group of 15 experts with the request for assessing the comprehensibility of the questions and the IT related features captured by these questions. In addition, the experts should test whether the digital version of the inventory was consistent and the overall structure and length were acceptable. The experts could enter their comments on the comprehensibility and feasibility into the online survey tool.

2.6 Model specification (Step 5)

The model specification rested on the assumption that all workflow descriptors contributed equally to the entire workflow composite score and that no difference in the importance of the sample workflows was made. In other words, information logistics in ward rounds for example was not considered more important than information logistics in discharges with regard to the workflow composite score. Similarly, the workflow descriptor *information and data* for instance was regarded as important as the workflow descriptor *integration*. Furthermore, all cells were weighted equally, e.g. the combination of *integration* and discharge received the same weight as *function* and discharge.

The specification comprised the calculation of the weights necessary to compute the WCS and further scores on the level of the individual workflow descriptors and the workflows. The model specification was performed top down by a mixed group of experts (Tab. 3) and was based on the refined framework (Fig. 1) and on the results of the content validity assessment (results of Step 3).

As Figure 2 shows the sum of all weights equalled 1. This total weight was evenly distributed to the 16 cells with a value of 0,0625 per cell. This distribution resulted in a weight sum of 0.25 for each workflow descriptor and for each workflow. Weights were given to features (e.g. “PC”, “tablet”, “notebook”) not to questions (e.g. “in- and output devices”) because they were the lowest level of information. These feature weights were calculated per cell by dividing the cell weight (0.0625) by the number of features in this cell. If for example four features captured the content of a certain descriptor-workflow-combination each feature had a weight of 0.0625/4 = 0.015625 (see example shown in the lower left cell of Fig. 2). As certain features related to different descriptor-workflow-combinations (see 2.3) their weight was calculated by the sum of the cell-specific weight per feature. We arbitrarily defined 40 points for the workflow composite score. Following the scheme of weights this led to a maximum value of 10 points per workflow descriptor score and per workflow score, i.e. 40 * 0.25 = 10.

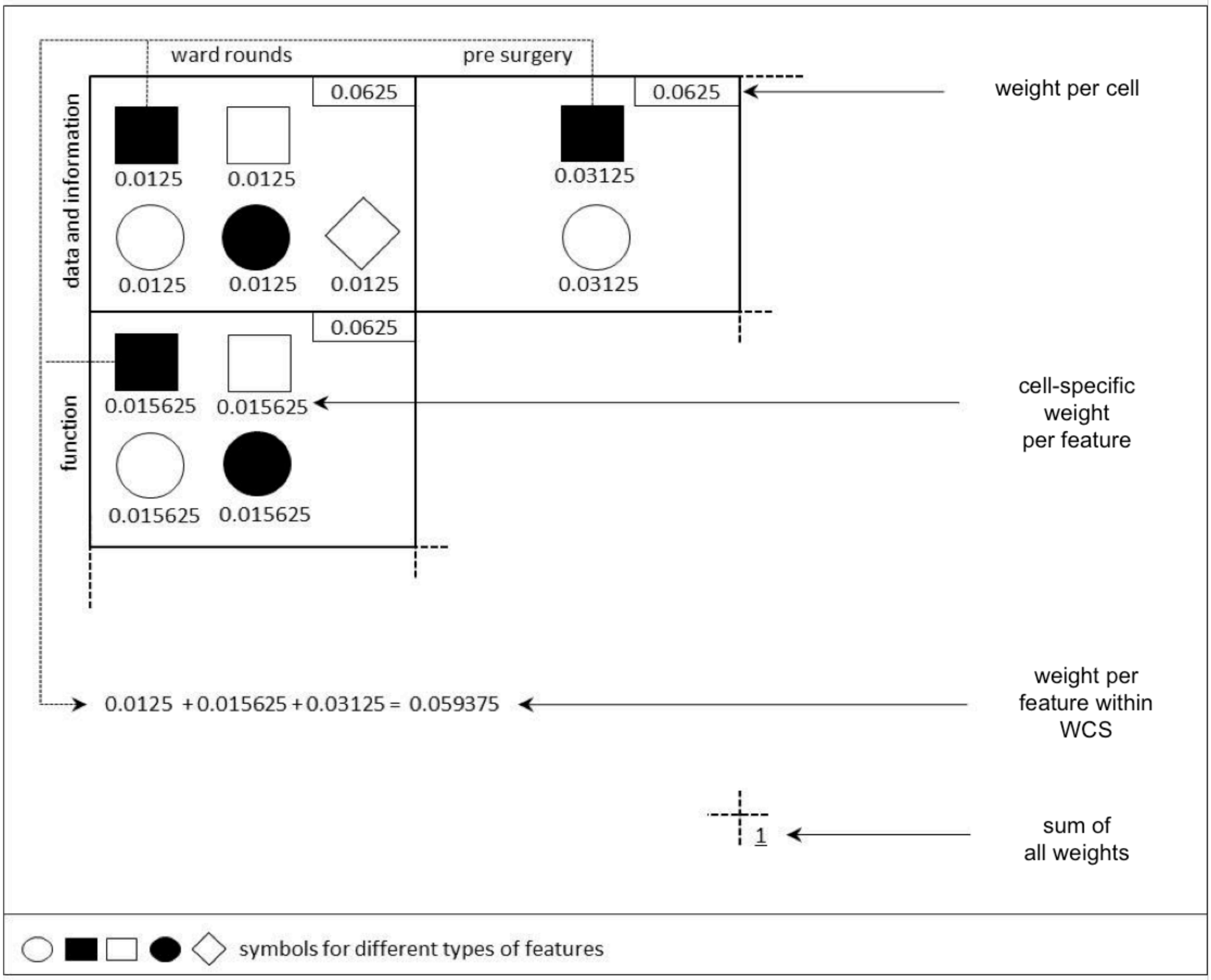

Figure 2: Model specification scheme, i.e. excerpt of the 16 cell matrix of workflow-descriptor-combinations with an example how to calculate cell specific weights per feature and weights per feature within the WCS.

2.7 Data capture and score computation (Step 6)

The final online inventory was sent to 1317 chief information officers (CIO) or persons with similar responsibilities in German hospitals. These 1317 individuals represented 1675 out of the 2006 German hospitals. No IT representative could be identified for the remaining 331 hospitals. The survey period lasted for 5 months from February to June 2013 and comprised five reminders. The survey took place within the IT Report Healthcare surveys, which are performed regularly in Germany and neighbouring countries [22]. For the purpose of this study, a subsample of hospitals with surgery and intensive care departments was selected from the responding institutions. We thus could be sure that all four workflows were relevant to these institutions.

Workflow composite scores were computed for all participating hospitals of the subsample pursuant to the specified model (Step 5). In case of missing values we applied common imputation methods, in particular substituting the missing value by the measures of central tendency (medians or the modal values).

2.8 Examination of the WCS reliability (Step 7)

We applied the odd-even method for splitting the inventory in two halves so that features from each of the workflow descriptor combinations were included. Split-half reliabilities [23] were computed for the WCS and for the workflow scores and the workflow descriptor scores. The split-half reliabilities were corrected using the Spearman-Brown formula [24]. All computations were performed using SPSS Version 21.

2.9 Examination of the WCS validity (Step 8)

We started examining the WCS validity by checking the overall distribution of the WCS and testing the arithmetic means for differences in known-groups comparisons [18]. We hereby distinguished between hospitals of different size, ownership and teaching status. These characteristics had been found to influence the number and type of IT applications [25, 26, 27]. Internal WCS validity was tested on the level of the workflows by correlating the workflow scores with the subjective ratings of the CIOs on how well IT supported the four workflows. To assess the external WCS validity we assumed that electronic health records (EHR) are instruments that are in principle built to support clinical workflows [e.g. 17] - among others purposes.

We therefore used two external EHR models to describe the degree of EHR adoption, namely the European Electronic-Medical-Record-Adoption-Model (EMRAM) [21] and the Electronic-Health-Record-Adoption-Model by Jha and colleagues [20]. We approximated these models according to the published descriptions and to the relevance of the IT related features for the clinical practice in Germany. As none of them could be used without modifications and as no proper publication existed in the case of EMRAM we called the two models EHR model 1 (modified EMRAM [21]) and EHR model 2 (modified Jha model [20]). Based on this starting position we allocated the IT related features captured by the questions in our inventory to the two EHR models. As the questions in our inventory were primarily derived from the HIMSS leadership surveys and the Jha model the allocation was straightforward. In the case of the Jha model we did not use the categories proposed by Jha and colleagues [20] but counted the number of applications available that met the criterion of the *comprehensive EHR* in order to yield a metric variable.

The WCS validity was finally examined by testing its practical usefulness in the context of IT benchmarks. To this end, 183 German hospitals that participated in the IT Report Healthcare survey (see Step 6) were approached with the request to evaluate the WCS. They had been given comprehensive material on their individual results with regard to the global WCS and its decomposition down to the feature level. Furthermore their results had been visualised in comparison to the results of their reference groups [14]. They were asked to assess the usefulness and comprehensibility of the WCS on a 4-point-Likert scale and the expected result of the WCS on a 3-point Likert scale.

3. Results

3.1 Research question 1

"What is a valid framework for the standardised measurement of IT support of clinical workflows that can lead to the construction of a workflow composite score (WCS) and what is a suitable WCS inventory, in the sense of a useful structure and useful IT related features (short: *features*) based on this framework?"

This question was answered in the steps 1 to 5.

First of all, results from assessing the content validity of the framework are presented (Tab. 2). These results were obtained by assigning the IT related features, which had been described in the various studies, to the four proposed workflow descriptors. The three experts involved agreed on the fact that all features in these studies could be mapped to the descriptors without exceptions. Hereby, the experts decided to assign the single features to one descriptor only, the primary descriptor. Pursuant to these allocations, all instruments put the greatest importance on the descriptor *function*. All other descriptors assumed various ranks of importance without showing any preponderance.

Table 2: Assignment of IT related features of published instruments to the four workflow descriptors

study	*data and information*	*function*	*integration*	*distribution*	sum
[10]	9	39	15	16	79
	11%	49%	20%	20%	100%
[3,29]	12	28	17	3	60
	20%	46%	29%	5%	100%
[11, 12]	18	34	10	28	90
	20%	37%	12%	31%	100%
[28]	11	13	6	3	33
	33%	39%	18%	10%	100%
[16]	27	30	6	21	84
	32%	36%	7%	25%	100%

These results showed that other approaches could be successfully mapped to the workflow descriptors and hereby gave evidence of the content validity of the framework.

The four workflow descriptors were then operationalised on the ground of the refined framework of the 16 cell matrix and its selected clinical workflows (Fig. 1). A total of 92 features were developed that could be captured in 50 questions in the final version of the inventory after the pretests. The 92 features that where captured by these questions were either related to only one descriptor and one workflow (specific feature), to several descriptors and one workflow (mixed features A) or vice versa (mixed features B) or finally to several descriptors and several workflows (general feature) (see table A3 of the electronic appendix)

Assessing the content validity on the level of the questions and the features yielded agreement in two discussion rounds among the experts (Tab. 3). Their judgment included both the allocation to the workflow descriptor – workflow combinations and the completeness of the questions and the features.

Based on the allocation of the features to the descriptor-workflow combinations and the matrix of weights (Fig. 2), weights for individual features could be computed of which Tab. 3 shows some examples.

Table 3: Example of IT related features and their respective weights (in %) within the WCS

Feature	Weight
Is the medical summary made available electronically to the general practitioners?	1.32%
How would you describe the architecture of your health information system?	4.09%
What is the degree of WiFi implementation in your institution?	4.79%
How many clinical units in your institution have mobile access to the patient data?	4.79%
How many clinical units have access to an electronic system that supports medical guidelines or clinical pathways?	5.35%
Is there a workflow management system integrated into your health information system?	6.60%
Please describe the availability of the *electronic patient record system* in your institution.	11.39%

3.2 Research question 2

"How reliable and valid is this workflow composite score?"

3.2.1 Data capture and score computation

The results of steps 6 to 8 contributed to answering the second research question.

After having shown the content validity of the inventory, it was disseminated electronically (Step 5) with an overall response rate of 19.7 % and with 183 being eligible for the computation of the WCS, i.e. having a surgery and ICU department. The 183 hospitals belonged to all types of size and ownership and hospitals in all federal states were represented (Tab. 4). Workflow composite scores were computed for each hospital and resulted in a symmetric distribution with an arithmetic mean of 23.4 (+/- 5.6 SD) out of the 40 points and a range of 9.2 (lowest) to 38.0 points (highest value) (Fig. 3).

Table 4: Arithmetic means and SDs of WCS in know-groups comparisons [n=183]

Group characteristics	WCS $\bar{x} \pm$ SD	Percentage within sample (absolute value)
Ownership		
private	22.3 +/- 5.9	18.0% (33)
public	23.6 +/- 5.5	82.0% (150)
Size (number of beds)		
1 to 399	22.3 +/- 5.6	53.6% (98)
400 to 799	23.7 +/- 4.4	30.0% (55)
800 and more	26.5 +/- 6.2	16.4% (30)
Teaching status		
no teaching hospital	22.3 +/- 5.9	32.2% (59)
teaching hospital	24.2 +/- 5.3	67.8% (124)

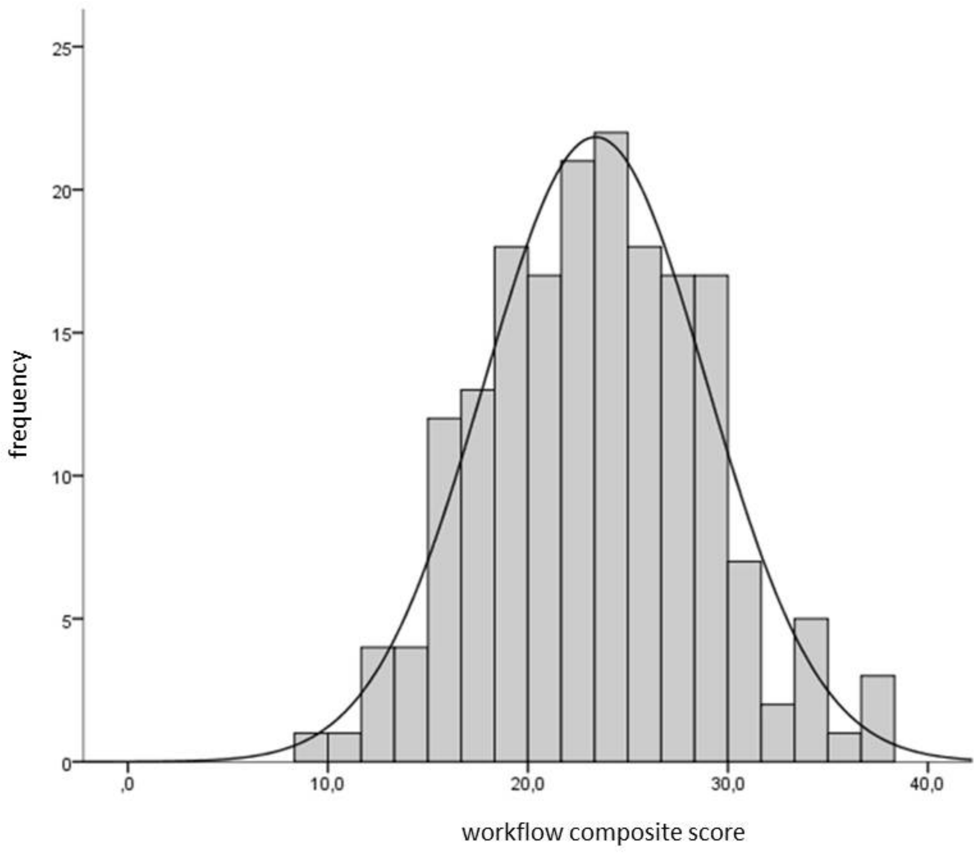

Figure 3: Distribution of the WCS (n=183 hospitals)

3.2.3 Reliability testing

Analysis of the split-half reliability for the WCS and the workflow scores yielded rounded Spearman-Brown coefficients between 0.72 and 0.89 (Tab. 5). Reliability coefficients of the workflow descriptor scores *data and information* and *function* were rather high with 0.98 and 0.89 respectively. There were only low reliability values for the workflow descriptor scores *integration* and *distribution* (Tab. 5).

Table 5: Split-Half Reliability - Spearman-Brown coefficients for WCS and workflow scores

	n	number of features	number of features half A	number of features half B	Spearman-Brown coefficient
WCS	113	92	46	46	0.886
Ward round score	117	76	38	38	0.885
Pre-surgery score	144	53	27	26	0.885
Post-surgery score	145	60	30	30	0.722
Discharge score	143	59	30	29	0.886
Data and information score	146	41	21	21	0.977
Function score	144	37	19	18	0.885
Integration score	167	9	5	4	0.359
Distribution score	183	13	7	6	0.127

3.2.4 Validity testing

Validity of the WCS was tested in the first instance computing the differences in known-groups comparisons (Tab. 4). Workflow composite scores differed between public and private hospitals and between teaching and non teaching hospitals with higher values for public and teaching hospitals. The score also rose with increasing number of beds.

Testing internal validity through correlations between workflow scores and the subjective rating of IT workflow support quality resulted in coefficients from 0.49 to 0.44 for ward rounds, pre- and post-surgery (Tab. 6) and a low coefficient of 0.18 for discharge. The WCS correlated with the EHR model 1 at r=0.42 and with the EHR model 2 at r=0.36 (Tab. 6).

Table 6: Testing internal and external validity (workflow rating were measured on a scale from 1 (very bad) to 5 (very good))

	n	r	p	workflow score $\bar{x} \pm$ SD	workflow rating Median (Q1 – Q3)
Ward rounds: subjective rating and workflow score	180	0.489	<0.01	6.1 ±1.5	3 (2.25 – 4)
Pre-surgery: subjective rating and workflow score	180	0.442	<0.01	5.9 ±1.4	2 (2 – 3)
Post-surgery: subjective rating and workflow score	180	0.457	<0.01	5.9 ±1.5	2 (2 -3)
Discharge: subjective rating and workflow score	180	0.179	<0.05	5.3 ±1.5	2 (2 -2)
WCS – EHR model 1	183	0.419	<0.01		
WCS – EHR model 2	183	0.364	<0.01		

3.2.5 Evaluation

Finally, the WCS was validated by evaluation. Out of the 183 participating CIOs of hospitals, 67 responded to the evaluation questionnaire (34% response rate). Over 4 out of 5 of the CIOs found the scoring model at least comprehensible and three quarters of them reported the WCS to be at least useful. A very large majority either expected or assumed the individual WCS result for their institution (Figure 4).

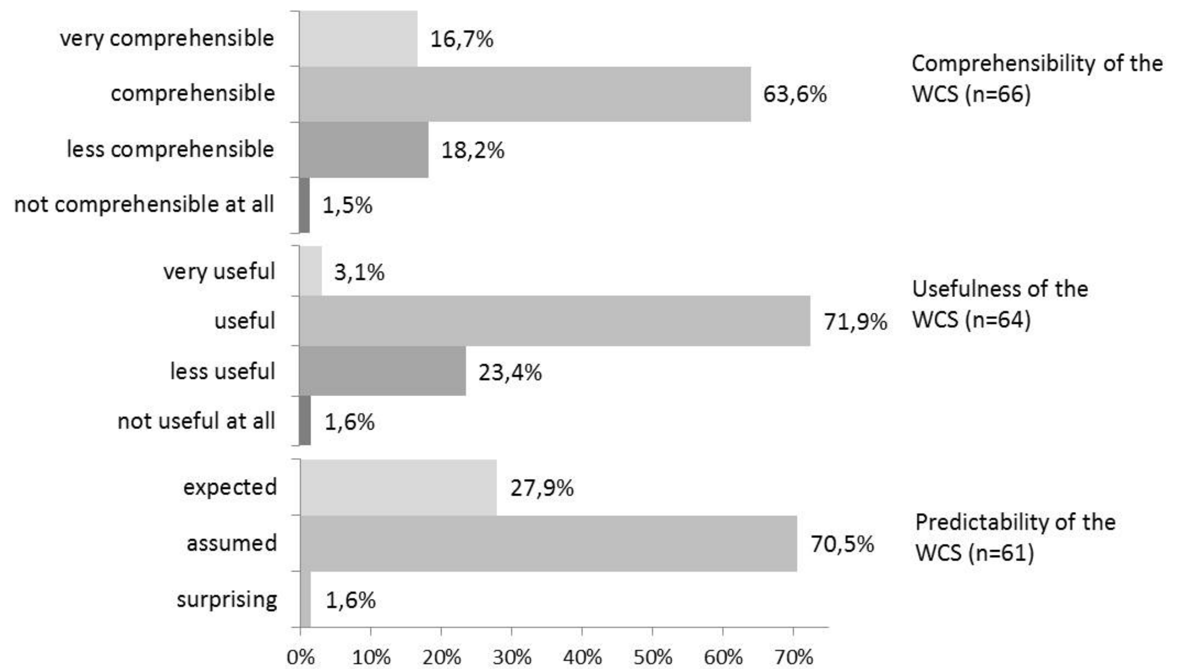

Figure 4: Evaluation results

4. Discussion

This study aimed at measuring the construct *clinical information logistics* via a workflow composite score and to our knowledge it is the first dedicated approach to reach this goal. *Clinical information logistics* was decomposed into the descriptors *data and information*, *function, integration and distribution*, which embraced the initial framework. It was validated by the comparison with published instruments during the course of this study. This framework was refined selecting representative clinical workflows that serve as concrete instances for the measurements. The four processes are sample processes, i.e. taken from the large “population” of processes. They were selected deliberately based on the criteria mentioned. Studying four core processes seems to be a good balance between depth-of-analysis and feasibility. There may be some variations in the clinicial processes across hospitals and across countries. We therefore tried to reduce the complexity and differences of each of the four workflows to a similar pattern of requirements based on the descriptors *data and information*, *function*, *integration* and *distribution* that characterises each type of workflow.

The final framework was thus constituted by a 16 cell matrix. The primary assumptions of all descriptors and workflows contributing equally to the WCS were confirmed by the expert discussions. The incremental phases for constructing the WCS then lead to an accepted and usable inventory and its application in a sufficiently large sample.
The WCS is a measure that was normally distributed in the sample with an average in the middle of its codomain. The WCS could discriminate between hospitals of different size, ownership and teaching status in a way that was congruent with what was expected from previous studies. Fonkych and Taylor [26] could show that the number and type of health IT systems available in the hospital increased with the size of the organisation. The same effect could be observed with teaching status in the sense that teaching hospitals had adopted more applications and functions [25]. It is also consistent with the literature that private hospitals had a lower WCS than public hospitals, which mirrors studies that showed lower adoption rates of clinical IT in private hospitals [27]. We can thus conclude that the WCS behaved in a well-predicted manner. The correlations of the workflow scores with the subjective ratings for the quality of IT support for these workflows lied in a medium range (between 0.4 and 0.5). Only one workflow, i.e. discharge, deviated from this result with a correlation of 0.2. A possible reason for the discrepancy between the discharge score and the rating is the different focus on what is important for discharge. Hospital CIOs might have been satisfied with IT discharge support even if their system did not provide a function to send clinical summaries outside the hospital. However, the missing communication with external health care providers contributed to low values in the score. Correlations between the global WCS and external criteria, i.e. the two EHR models, yielded moderate values of about 0.4. This shows that the WCS and the EHR models measure concepts that overlap but are not identical. We did not expect the correlations to be much higher because both EHR models primarily address IT functions. EHRs are meant to support clinical workflows but it is not their singular purpose. The evaluation results of the practical use of the WCS in the context of IT benchmarking give hint at the acceptance of the score in terms of comprehensibility, usefulness and expectation in the CIO community. Altogether, these different measures of validity act as pieces in a puzzle and contribute to the overall interpretation of the WCS to measure what it intended to measure. However, caution is still advisable because the WCS could not be correlated against a gold standard. This is because no such gold standard exists and the questions or subscales in other instruments that cover workflow issues could not be used in our validation because we did not include them 1:1 in our survey. Another point is the expertise required to give account of the quality of IT support of clinical workflow. Do CIOs have enough insight into the clinical world or is the clinicians’ judgment needed? We therefore believe it necessary to carry on the validation work.

Reliability measures of the WCS yielded highly satisfying results for the most, i.e. for the WCS as such, all workflow scores, and the scores for the workflow descriptors *data and information* and *function*. The split-half correlations for the workflow descriptors *integration* and *distribution* in contrast were rather low. This was probably due to the fact that not as many features covered these descriptors as compared to the other two descriptors. With a few features at hand splitting these subscale into two halves could have resulted in the two halves measuring different aspects of *integration* and *distribution*. More redundancy in the features in these descriptors seems desirable.

We chose a top-down approach in this study for decomposing *clinical information logistics* into its descriptors. This procedure provided valid results. A top-down approach, however, does not preclude a bottom-up attempt. Our next step therefore is to calculate confirmatory factor analyses and based on these results to consider additional exploratory statistical approaches when appropriate.

The procedural model proposed by MacKenzie and colleagues [18] provided a very useful framework for conducting this study and we did not exploit all possibilities by far. The purification and the refinement of the inventory and its questions is described in great detail and gives a reason to perform more in-depth analyses. Furthermore the model specification definitely needs additional studies. In our work, we specified an internal model, however, MacKenzie and colleagues [18] also have construct models on mind, i.e. models that reflect the complex network of antecedents and consequences of the construct measured. One of the crucial questions therefore is: What are factors influencing *clinical information logistics* and to which extent do they influence it? This question is closely connected with the adoption and usage rates of certain applications and functions and the respective promoters and inhibitors. This type of work has gained much ground in the wake of the Meaningful Use Program [e.g. 30, 31, 32]. But also: What impact does *clinical information logistics* exert on health outcomes and on health care outcomes? This affects efficacy and quality of care, patient safety and patient-centred care in as much as cost effectiveness, efficiency and staff satisfaction – just to name a few endpoints. For both types of questions the WCS can serve as an important measure, in terms of an independent variable (predictor) as well as the dependent variable (criterion).

5. Conclusions

This study resulted in the proposition of a workflow composite score to measure the construct clinical information logistics. The score was tested for reliability and validity and encouraging results could be obtained that suggest the further utilisation of the WCS. This study presents the first but the most significant steps towards a WCS. As the construction followed a top-down approach the next step will be to validate the score in a bottom-up approach (e.g. with factor analyses). On top of that, the inventory might need to be refined in a limited way as described. The goal is to establish the WCS as a constant indicator for the IT support of clinical processes in German hospitals and beyond. As the WCS does not assume ideal workflows as a gold standard but measures IT support of clinical workflows according to descriptors validated by the international literature, a high portability of the WCS to other hospitals in other countries is very likely. One limitation and likewise a challenge might be the trade off between a most detailed and informative indicator and a universally valid construct. In this sense, the WCS will contribute to a better understanding of clinical information logistics.

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Beitrag 4: The Status Quo of Information Management in Hospitals - Results of an Online Survey

Titel	The Status Quo of Information Management in Hospitals-Results of an Online Survey
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Link	subs.emis.de/LNI/Proceedings/Proceedings259/685.pdf
Copyright	Lecture Notes in Informatics (LNI)

Tabelle 5. Überblick Beitrag 4

The Status Quo of Information Management in Hospitals -Results of an Online Survey

Christian Kücherer[1], Jan David Liebe[2], Michael Schaaf[3], Johannes Thye[2], Barbara Paech[1], Alfred Winter[3] and Franziska Jahn[3]

Abstract: Context: Information Management (IM) departments in hospitals provide IT services supporting patient care and administrative hospital functions. Complexity and impacts of IT failures are continuously increasing. Therefore, professional IM departments are necessary, even though their importance is commonly underestimated. **Objective:** Little is known about the organization and variety of IM departments in German hospitals. Therefore, we want to characterize their capabilities. In this paper, we present a study that analyzes the current status of IM in German hospitals in the dimensions (i) organization of IM departments, (ii) educational degree of Chief Information Officers (CIOs), (iii) communication of the CIO with the hospital management, (iv) usage of IT-process- frameworks, and (v) application system categories used for IM-related tasks. **Method:** The evaluation is based on an online survey of 134 CIOs. The survey questions were developed according to domain-specific literature, the SNIK-ontology, and interviews with domain experts. The survey questions were improved by a pretest. **Results:** The survey indicates that most of the CIOs are graduates in informatics with 13 years of experience, who are responsible for one hospital without being member of the hospital management. CIOs communicate in weekly formal meetings with the hospital management where they discuss projects, finance, security, and critical IT- and hospital services. Most IM departments do not use IT-process frameworks, but nearly all of the IM departments use ticketing systems, network management systems, project management tools, collaboration tools, BI tools, and ERP systems. The results show, that IM departments are generally well organized with the potential for improvement in IT-process-frameworks and application systems for IM functions.

Keywords: information management, hospital, online survey, application systems, CIO, IT department, ITIL, management communication.

1 Introduction

Information management (IM) aims at the systematic management of information systems. An information system can be defined as the socio-technical subsystem of an enterprise comprising processes, information technology, and humans in their information processing roles. In hospitals, the permanent responsibility for life and death of patients and effectiveness rather than efficiency determine the activities of the medical professionals [LR13], [MC09]. Therefore, IM in hospitals has to consider organizational and legal requirements. However, information systems in health care are often said to lag behind information systems in industry by a decade. Several German studies support the existence of this felt gap. Two studies published in 2008 revealed the low maturity of applications in German hospitals and low IT budgets in comparison to industry [LKH08], [MSM08]. So far little attention has been paid to the internal structures, IM functions, and application systems used in IM departments (synonyms ICT or IT department). According to Winter et al. [Wi11], IM in hospitals has to differentiate between of strategic, tactical, and operational IM. Strategic IM plans, monitors, and directs the information system's long-term development. Tactical IM updates certain parts of the information system through projects. Operational management has to ensure the information system's daily operation. For all these IM tasks, called the IM functions, clear procedures, applications, competent staff, and a highly skilled manager in the form of a CIO is needed, who is responsible for the functioning of the IM department. Several studies indicate that business success is correlated with IT competencies or the adoption of standardized processes [MSM08], [PSBQ10], [MK11]. Therefore, professional IM departments are an important success factor for information systems.

The overall goal of this paper is to present a first descriptive evaluation to characterize the capabilities of IM departments in German hospitals. The goal is structured by the application of the Goal Question Metric (GQM) approach [Va02] by Basili et al. and is formulated as: *Determine* the capabilities of IM departments in German hospitals *with respect to* (D1) the CIO's position in the hospital management hierarchy, (D2) his/her educational background and experience, (D3) his/her communication habits with the hospital management, (D4) the use of IT-process-frameworks, and (D5) IM-specific applications used *for the purpose of* a professional and reliable strategic, tactical, and operational management *in the context of* IM divisions of German hospitals *from the*

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viewpoint of researchers and CIOs. We address the aforementioned goal by investigating 9 research questions (RQs), as documented in Table 1. The column *research question* shows the RQs, the column *dimension* shows the mapping of RQ to the dimensions D1-D5 in the goal. We expect the chosen RQs to be of high interest in the IM community.

RQ.ID	Research Question	Dim
RQ.1	How is the CIO positioned in the hospital management hierarchy?	D1
RQ.2	Which educational background does the CIO have?	D2
RQ.3	Which work experience does the CIO have?	D2
RQ.4	How does the CIO communicate with the hospital management?	D3
RQ.5	How often does the CIO communicate with the hospital management?	D3
RQ.6	What are major issues in the communication with hospital management?	D3
RQ.7	Which IT-process-frameworks are used for strat/tact/operat.IM functions?	D4
RQ.8	What is the level of utilization for the ITIL-framework?	D4
RQ.9	Which IM-specific application systems are used to support IM functions?	D5

Tab. 1: Research questions and the dimensions (Dim.) of the goal

The position of the CIO in the management hierarchy is interesting since it shows the status of the CIO and his/her decision power (RQ.1). The educational background and the work experience (RQ.2) of CIOs influence the organization and standard-orientation of the IM department. The work experience (RQ.3) of CIOs does highly influence the organization of the IM department and decisions. Communication is a key management factor. Thus, we are interested in the CIO's communication habits (RQ.4). The form and frequency of communication (RQ.5) with the hospital management indicates the quality of relationship between these two. The issues the CIO discusses with the hospital management (RQ.6) are interesting since they show important aspects of a CIO's daily business. IT-process management frameworks (RQ.7), such as ITIL, COBIT, and PRINCE2, allow reliable and controlled operation processes to support IM functions. The level of utilization of IT process management frameworks (RQ.8) shows to which extent the IM departments act according to the frameworks. IM departments use a variety of application systems to support several IM functions. We want to understand which classes of application systems are used for which IM functions (RQ.9).

This paper is structured as follows: Section 2 explains the methodological background of the survey design and the development of the study questions. The evaluation of the online survey and the answers to the research questions are given in Section 3. Section 4 discusses the results and the insights gained in this study. Potential threats to validity are discussed in Section 5. The conclusion and ideas of future work is given in section 6.

2 Methodology

This section describes the study design process used to construct the online survey, and in brief the performed online survey.

2.1 Survey Design

In the development of the study, four roles were involved. First, the editor team consisted of two persons familiar with the hospital IM domain and basic questionnaire-design. Second, the survey team consisted of two persons who have significant experience with study- and questionnaire-design and are able to rate the defined questions from a survey point-of view. Third, the domain expert is a person, who is familiar with the hospital IM domain and all variations of different hospital IM departments. Fourth, the beta testers, a heterogeneous group of 10 persons who completed the questionnaire as CIO and gave detailed feedback. The survey team also contributed to the selection and review process.

Figure 1 shows the process of the survey design. In the selection process, the editor team formulated the goal and question proposals of the survey according to the GQM scheme, based on three sources. For the structuring of IM functions in hospitals, we adopted the strategic, tactical, and operational IM classification as proposed by Winter et al. [Wi11]. In order to extend the hospital-specific work of Winter et al., the domain-independent IM work of Heinrich/Stelzer [HRS14] has been used. For all topics that relate to tactical IM, i.e. project management, the work of Ammenwerth et al. [Am15] provided a good structure of tasks and best practices. These sources were used to create an ontology of IM in hospitals (SNIK- ontology) [Sc15] that contain IM-specific concepts. The SNIK ontology provided a glossary for the process of questionnaire construction and the formulation of the question and answer sets. The question proposals were refined, restructured, or rejected with the help of domain expert interviews. In the review process, the finalized set of questions was discussed with the survey team. Questions that did not match the survey criteria were redesigned or were refused. The survey criteria for valid questions are: (i) question must contribute to the goal of the survey (ii) question must be easily understandable (iii) question must be answerable by most of the hospitals and suit most of the IM settings (iv) evaluation must be reasonably practicable (i.e. limited number of free-text questions) (v) filter questions may be applicable to reduce the effort for participants. In the pretest phase, the survey team created a pretest version of the online survey based on the questions from step 2 in the tool Unipark[4]. This online survey was evaluated by the beta tester, domain experts, editor- and survey team. All involved roles gave sound feedback and proposed changes to the questions, which were incorporated in the next iteration of the selection and review process. The pretest was iterated twice. Finally, the online survey was executed in the phase online survey.

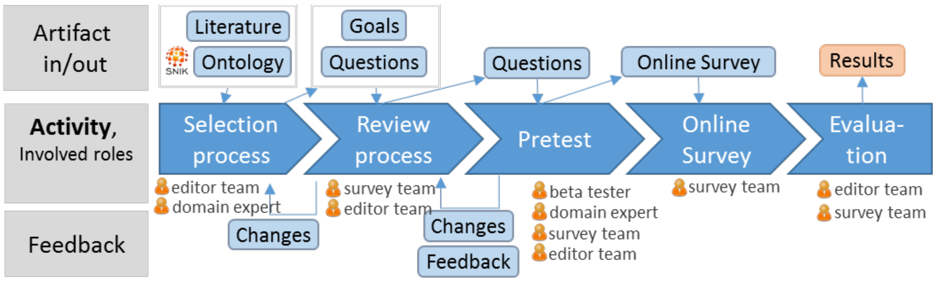


Fig. 1: The questionnaire development and study design process

2.2 Conducting the Online Survey

The study is designed as a cross-sectional study with possible repetitions. The online survey[5] comprises 59 questions and contains also questions for other goals, not focused in this article. There are approx. 1980 hospitals in Germany [St15], some of them belonging to a group of hospitals. Thus there is a lower number of CIOs. We contacted N=1284 CIOs via e-mail with an invitation to participate in the online survey. The CIO's E-Mail addresses were available to the survey team from previous surveys.

We collected the data from the online survey between February 12, 2016 and the beginning of April 2016. The survey resulted in 176 analyzable questionnaires, which are completed at least half. 134 of the 176 were completely filled. This results in a response rate of 13.7 %. From the participating hospitals were 11.8 % private hospitals, 37.2 % public hospitals, and 51.0 % in independent nonprofit organizations (n=176).

3 Status of Information Management in German Hospitals

This section describes the status of IM in German hospitals by investigating the research questions in Table 1. The number of answers considered is indicated as n and the standard deviation as σ for each evaluated question. The question number in the questionnaire is indicated by Q. We evaluated the stated questions, whereof the questions marked with */F* include the evaluation of free text fields.

3.1 Findings for RQ.1: The CIO's Position in Hospital Management Hierarchy

The position of the CIO in the hospital management hierarchy, as requested in RQ.1, depends on the CIO's inclusion into the hospital management, the job description, and the number of subordinated hospitals. Slightly more than half of the CIOs (54.9 %, n=95) are responsible for a single hospital (Q3, total n=173), whereas all others are responsible for more than one hospital (45.1 %, n=78). Those CIOs who are responsible for more than one hospital take care of 3.97 hospitals in average (σ = 6:394, n=78). Only a minority of 4.7 % (n=8) are female CIOs, whereas 95.3 % of the CIOs are male (Q5, total n=171). All participants were requested to name their job description (Q6/F, total n=170), which show a great variety. However, 82.9 % of the job descriptions indicate an executive status of the participant by containing the keywords leading, leader, manager, head of, etc. Interestingly, only in 3.5 % of the job descriptions, the term CIO is contained explicitly. The majority of 94.4 % (n=152) of the CIOs are not members of the management (Q18, total n=161). **Summarizing RQ.1**, we can state in most cases the CIO is male and not a member of the hospital management, but in the majority of the cases the job description reveals the CIO's executive status. Slightly more than half of the CIOs are responsible for one single hospital and in all other cases they are responsible for up to four hospitals.

[4] http://www.unipark.com/de/
[5] The final online survey questions are available for download http://www.snik.eu/de/Ergebnisse/fragebogen2016.pdf, available in German only.

3.2 Findings for RQ.2: The Educational Background of CIOs

Information about a professional training or graduate occupation, and certificates characterizes the educational background of CIOs (RQ.2).

More than half of the participants (52.5 %, n=94) hold a graduate degree from a university or a university of applied sciences. Nearly half of the participants (40.2 %, n=72) completed a professional training, six participants (3.4 %) hold a PhD, and seven participants (3.9 %) have earned a GMDS medical informatics certificate (Q10/F, total n=179). Those participants that completed a professional training gave information about their specialization of education (Q11, total n=96). 23 participants (24 %) have a professional training in business administration, four participants completed a training in nursing or medical care (4.2 %), two participants finished a medical or therapeutic training (2.0 %) and the vast majority of 49 % (n=47) are qualified IT specialists. Other trainings were completed by 20 participants (20.8 %) in the areas of electronics, chemistry, and mechanical engineering.

Degree	University (%, n)		University of applied sciences (%, n)	
Diploma	32.7 %	34	36.5 %	38
B.Sc.	1.9 %	2	8.7 %	9
M.Sc.	5.8 %	6	6.7 %	7
State examination	3.8 %	4	2.9 %	3
Magister (M.A.)	1.0 %	1		

Tab. 2: Academic degrees.

Regarding the academic degree (Q12, total n=104), Table 3 shows that a Diploma is most common, nearly equally distributed between universities and universities of applied sciences. In contrast, B.Sc. and M.Sc. degrees are still very uncommon. These statements were not introduced until several years after the Bologna Process in 1999 in Germany has begun. Due to the work experience (see findings for RQ.3 in subsection 3.3), only a minority of graduates with M.Sc. and B.Sc. degrees already are in a CIO position. Other degrees are state examination (n=7) and Master of Arts (n=1) that are held by a minority of 7.7 %. The majority of CIOs has graduated from a university of applied sciences. The specialization in academic studies (Q13, total n=117) is in 30.8 % (n=36) informatics and business informatics, followed by 16.2 % (n=19) in business administration and 14.5 % (n=17) in engineering sciences. Only 12 participants (10.3 %) specialized in medical informatics. Medicine, natural sciences, and other specializations make up 28.3 % (n=33). Although medical informatics being a field of studies preparing for the job of hospital CIO, there are fewer graduates in medical informatics than in engineering. The subject of a PhD (Q14/F, total n=6) is in 2 out of 6 cases related to biology and in 1 out of 6 cases related to physics. One participant stated a topic related to computer tomography, which can be located in medical informatics or computer science. Two participants did not state their topic. **Summarizing RQ.2**, it can be said that slightly more than half of the CIOs have graduated with a diploma or a master's degree in a subject related to informatics or business administration, whereas a PhD is an exception. Less than half of the CIOs have completed a professional training.

3.3 Findings for RQ.3: The Work Experience of CIOs

The average work experience of a CIO in this position is 13.52 years, whereas the minimum was 0 and the maximum 35 years (Q7, n=170, σ = 8; 738). In average, a CIO is with his/her employer for 11.54 years (Q8, n=170, σ = 8:093). **Summarizing RQ.3**, we can say that the typical CIO has more than 13 years of experience in his/her job, and stays more than 10 years with the same employer.

3.4 Findings for RQ.4: Communication of the CIOs with Hospital Management

The communication with the Hospital Management is supported by visual aids that contain or display information in the form of office documents, reports, or dashboards. Documents can be digital documents presented on displays or projectors, or they can be printouts of digital documents. Digital documents such as office documents and printouts are used frequently, as shown in Table 4a (Q22/F, total n=215). Information from reporting tools or dashboards is less frequently used. Interestingly, only a minority does not use visual aids at all. Other visual aids mentioned are flip-charts, whiteboards, and video conferencing systems. The most important contents of the visual aids (Q23, total n=149) are decision memos, recommendations, trends, and comparisons of departments or facilities, as depicted in Table 4b. Other contents mentioned were mind-maps, meeting minutes, or e-mails.

Visual aids	%	n
digital documents	62.6	134
printouts of documents	48.8	105
reporting tools, dashboards	23.7	51
no visual tools	3.7	8

(a) Visual aids for communication

Content	%	n
decision memos	85.2	127
recommendations	73.2	109
trends	72.0	108
comparisons of facilities	29.5	44
comparisons of departm.	22.1	33

(b) Content of visual aids.

Tab. 3: Visual aids and their content.

The contents of digital documents (Q24, total n=147) in the form of tables (17.4 %, n=115) and text (17.7 %, n=117) are considered to be more important than diagrams (13.9 %, n=92). The same applies to printouts of documents: tables (12.1 %, n=80) and text (14.2 %, n=94) are considered important, whereas diagrams (9.7 %, n=64) are less important. Interestingly and intelligibly is that diagrams (6.0 %, n=64) and tables (5.9 %, n=39) are more important when dashboards are used, compared to text (3.2 %, n=21). **Summarizing RQ.4**, it can be said that CIOs communicate with the hospital management by mostly using electronic documents with text and tables. The electronic documents contain decision memos, recommendations, and trends of the IM department. Dashboards focus on diagrams and tables, but are surprisingly less frequently used.

3.5 Findings for RQ.5: Frequency of Communication with the Hospital Management

CIOs communicate with the hospital management in 42.3% (n=91) once a week. A minority of 16.7 % (n=36) of the participants communicate monthly. Only 10.7 % (n=23) communicate daily and only 1.4 % (n=3) communicate less frequently than yearly (Q19, total n=154). Formal meetings are used in 54.9 % (n=85) of the cases to communicate with the hospital management. In 45.1 % (n=70) of the cases, CIOs rarely have a formal meeting (Q20, total n=155). Informal meetings with the hospital management (Q21, total n=155) are used rarely in 66.5 % (n=103), whereas in 33.5 % (n=52) of the cases they were used frequently. Therefore H.6 is true. **Summarizing RQ.5**, it can be said that most of the CIOs communicate weekly in a formal meeting. Informal meetings are used only rarely.

3.6 Findings for RQ.6: Major Communication Issues with the Hospital Management

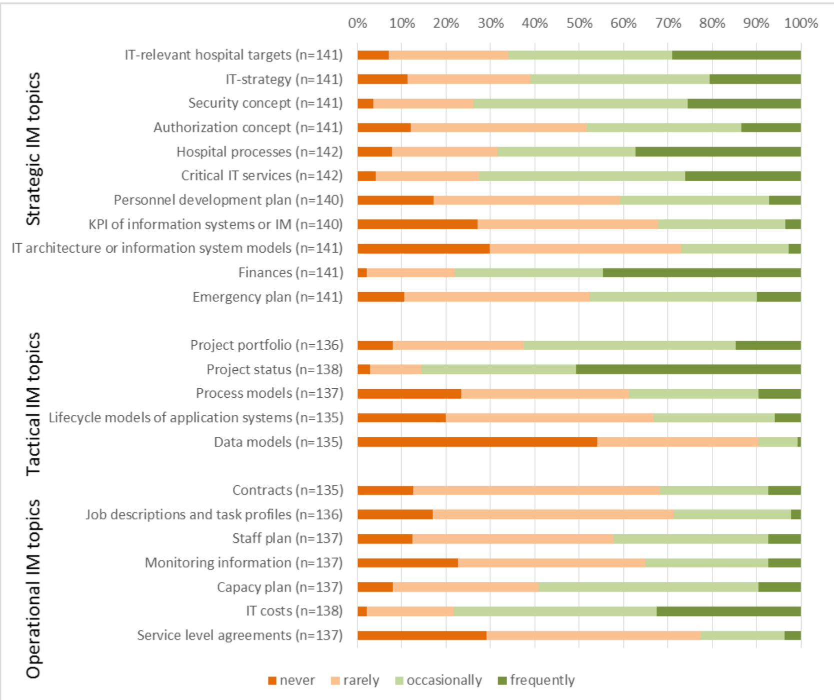


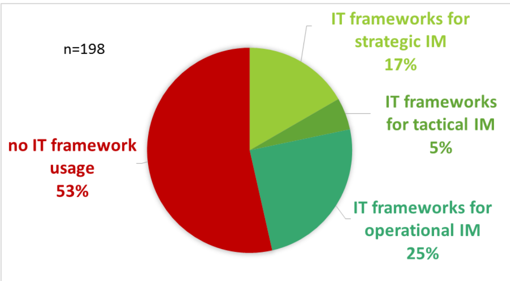
Fig. 2: Observed frequency of used strategic, tactical, and operational information

Nearly all information shown in Figure 2 with its frequency is used in the communication with the hospital management. When considering occasional and frequently used information together, the information most commonly used is project status, financial issues, IT costs, security concepts, critical IT services, hospital processes, and IT-relevant hospital targets. Other strategic information subject for communication (Q40/F, total n=141) that was stated by participants is: daily business, IT incidents, Hospital information systems, interoperability to medical technology, IT requirements from other departments, responsibilities. Other tactical information (Q49/F) is information supplied by users, cost plans, and time schedules.

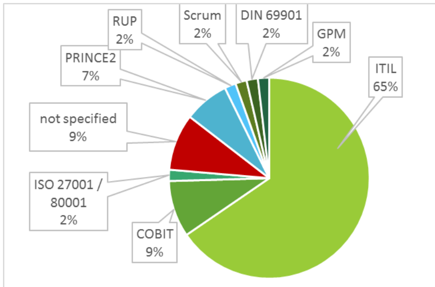
Summarizing RQ.6, it can be said that major communication issues are related to projects, finance, security, critical IT- and hospital-services, and IT-relevant hospital targets. Monitoring information (status of helpdesk, system workload) is rarely issues.

3.7 Findings for RQ.7: IT-Process-Framework Usage

The survey reveals the IM categories, in which IT frameworks are used, as shown in Figure 3a, (Q16, n=198). A majority of 53 % does not use a framework at all. For operational IM functions, 25 % adopt an IT framework, followed by 17 % for strategic IM functions. For tactical IM functions, only a minority of 5 % adopt an IT framework.



(a) usage of IT frameworks in categories of IM



(b) IT frameworks frequency

Fig. 3: IT framework usage

The most frequently used IT framework (Q37/F, Q45/F) is ITIL (65 %), followed by COBIT (9 %), and PRINCE2 (7 %), as depicted in Figure 3b. Other IT frameworks such as ISO 27001/80001, RUP, Scrum, DIN 69901, and GPM (all 2 %) were mentioned each by one participant only, and therefore do not play a significant role. Interestingly, CMMI and PMBOK are not used at all. ITIL can be viewed as both, operational and strategic IM. The IT-governance framework COBIT covers strategic, tactical, and operational IM aspects. As a project management framework, PRINCE2 is a tactical IM framework. **Summarizing RQ.7**, it can be said that for strategic IM ITIL and COBIT are used, for tactical IM PRINCE2 is used and for operational IM ITIL and COBIT are used.

3.8 Findings for RQ.8: The Level of Utilization of the ITIL-Framework

ITIL Process	not adopted		ad. planned		partially ad.		fully ad.	
Service strategy	34.8 %	16	19.6 %	9	43.5 %	20	2.2 %	1
Service design	28.3 %	13	28.3 %	13	39.1 %	18	4.3 %	2
Service transition	29.8 %	14	21.3 %	10	42.6 %	20	6.4 %	3
Service operation	10.6 %	5	14.9 %	7	53.2 %	25	21.3 %	10
Cont. Service improvement	32.6 %	15	32.6 %	15	26.1 %	12	8.7 %	4

Tab. 4: Degree of ITIL process adoption (ad.) for operational IM (rows present % and n).

Table 5 shows the degree of ITIL process adoption (Q57, n=47), whereas 36 participants adopt at least one of the ITIL processes partially or fully. Service operation is adopted by 35 participants partially or fully. Interestingly, more than 70 % use ITIL and most of the participants adopted it partially. It is surprising that strategy, design, and transition are adopted partially by many participants (43.5 %, resp. 39.1 %, resp. 42.6 %). **Summarizing RQ.8**, it can be said that ITIL service operation has the highest level of utilization, followed by service transition and service strategy.

3.9 Findings for RQ.9: Application System Categories for IM Functions

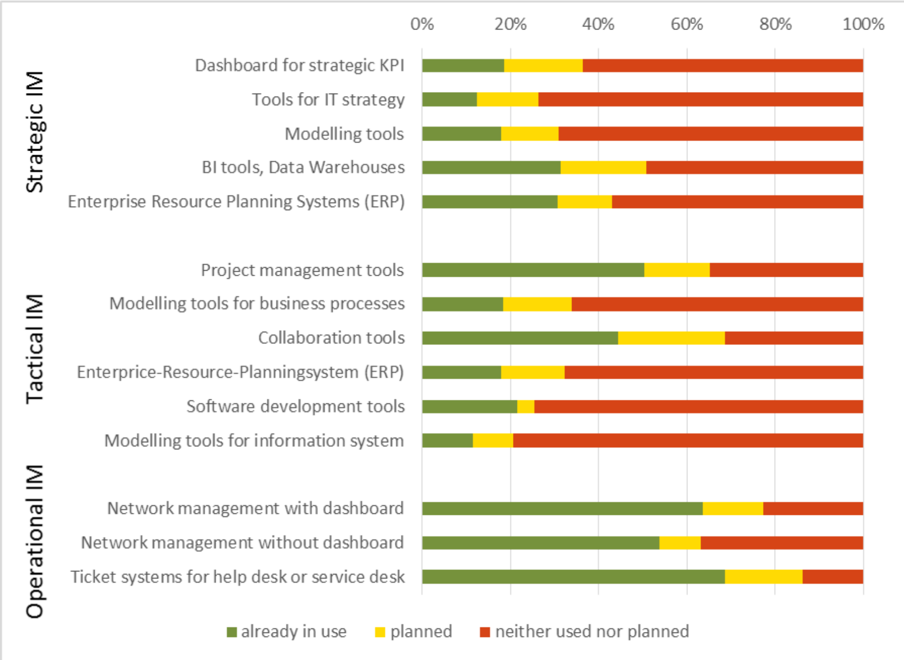


Fig. 4: Application systems used for IM functions

IM departments apply several tools in the form of application systems for IM functions (RQ.9). Since there is a great variety of different tools from different vendors, we examine the categories of application systems. For instance the category of *project management* application systems comprise the products Microsoft Project, inloox, FreeProject, and ProjectLibre. Figure 4 shows the distribution of application systems categories used for strategic, tactical, and operational IM (Q38, Q47, Q53). Interestingly, the vast majority of IM departments does not use application systems for various IM functions except for project management (n=68, total n=138), collaboration (n=61, total n=138), network management (n=79, total n=138), and ticketing (n=94, total n=138). In consequence, these IM functions seem to be important and complex and therefore require tool usage. For strategic IM functions, mainly BI tools and Data Warehouses and ERP systems are used by 31 % of the IM departments. Only 30 % of IM departments use ERP systems for strategic IM. Project management tools and collaboration tools (SharePoint, Wikis etc.) have a high popularity for tactical IM functions. Network management systems with dashboards and ticketing systems for help- or service-desks have an extensive use of 57 % resp. 68 % in operational IM functions. Participants have additionally mentioned (Q39/F, Q48/F, Q54/F) that they use documentation tools and knowledge management tools (wikis and mind maps) for tactical and operational IM functions, as well as server-/client-management systems and software distribution systems for operational IM functions. **Summarizing RQ.9**, it can be said that most of the IM departments do not use application systems for strategic and tactical IM functions, but do almost always use application systems for operational IM functions. When application systems are used for IM functions, they are (in order of frequency) ticketing systems, network management systems, project management tools, collaboration tools, BI tools, Data Warehouses, and ERP Systems.

4 Discussion

In the following, we relate our study results to former studies on CIOs and IM in hospitals. Whereas our study aimed at the analysis of internal functions, application systems, certification, and staff-related issues of IM departments in hospitals, the study by Leimeister et al. [LKH08] from 2008 focused on strategic IT goals, IT cost, and the functionalities and user satisfaction in the context of hospital information systems. In our study, we could confirm some characteristics of hospital CIOs that did not change in the past 8 years. Regarding RQ.1, the CIO's position, there is still only a very small number of „real" CIOs who are officially named „chief information officer". The results of the survey indicate that the hospital management knows about the importance of the IM department, although they do not organize the IM department as an inherent part of the hospital management. Regarding RQ.2, the educational background, the number of CIOs holding an academic degree (52.5 %) was comparable to the corresponding value in [BMB06] (59.5 %). Interestingly, only few CIOs have graduated in medical informatics, although they are supposed to be domain experts. There might be two reasons: first, there are only few graduates or second, the position of a CIO combines management functions with domain knowledge acquired on the job. The work experience of CIOs of 13 years with the same employer for 11 years as investigated by RQ.3 indicates a strong relationship between hospital management and the CIO. The observed steadiness is of high importance for continuous and reliable management, and the strategic alignment of IM departments. Concerning the communication between the CIOs and the hospital board (RQ.4 and RQ.5), Burke et al. [BMB06] associated CIOs reporting to the CFO (Chief Financial Officer), the CEO (Chief Executive Officer), or the COO (Chief Operations Officer) and the revenues of the hospital. They found out that reporting to the CFO correlated with higher revenues in American hospitals. Our focus on the frequency of contact and the topics which are relevant in the communication between the CIO and the hospital board add another, more qualitative view on the relationship between the CIO and the hospital board. The communication in weekly, formal meetings indicates an appropriate and purposeful cooperation of IM department and hospital management. Regarding RQ.6, the observed issues in communication were expected, especially finance and security topics. Interestingly, helpdesk and system workload rarely are issues. The adoption of ITIL in hospitals (RQ.7) of five European regions was analyzed by Hoerbst et al. [Ho11] in interviews conducted in 2008. At that time, only 5 out of 75 participating hospitals in Austria, Bavaria, Slovakia, South Tyrol, and Switzerland had already implemented parts of ITIL processes. Now we can see that the adoption of ITIL has increased over the past few years. However, 53 % of the hospitals still do not use a framework at all. In these cases the management of various IM functions has the opportunity to improve. The level of ITIL process utilization (RQ.8) shows the operational importance of the ITIL framework. However, it also shows the strategic utilization, which is surprising for us. Regarding RQ.9, the evaluation of the categories of application systems used in IM departments shows a clear deployment of tools for operational IM functions. Obviously, there is a lack of usage for strategic and tactical IM functions. Application systems for those IM tasks might just not be necessary or there might be a high potential for customized tools that support efficient IM functions.

5 Threats to Validity

The threats to validity of this study are structured according to Wohlin et al. [WHH03]. **Construct validity** considers whether the study measures what it claims [WHH03]. This study is a cross-sectional study that evaluates the capabilities of IM departments in German hospitals. Survey questions were designed by the use of literature and were subject of a review process and a pretest. Nevertheless, IM departments are different. Therefore, the questions allow to capture a wide range of possibilities. By comments in free text fields, we enabled the participants to submit additional information. Questions might be misunderstood or some participants might not be familiar with the IM classification. Therefore, we performed a review process and a pretest. We also gave examples and explanations in the questions that help to understand terms and grouping. **Internal validity** determines the extent of conclusions that can be drawn from a study, in particular by eliminating the bias of the study [WHH03]. Participants might bias this study, since only interested persons contribute to the survey. Therefore, the set-up of non-participating IM departments remains unknown. This problem is mitigated by motivating the participants with an incentive[6], an invitation sent by a professor of medical informatics, and the collaboration with the health IT report [Hü14] research group. Another threat to validity is that non-CIOs could also have conducted the survey. We mitigated this by addressing the invitation to CIOs only, which is evident by the job descriptions in RQ.1. There were no non-CIO-like job descriptions given. **External Validity** describes the possible generalization or transfer of the study results to other situations [WHH03]. This study targets German hospitals and might not be transferable to other countries. As the focus is strictly on IM in hospitals, the results cannot be transferred to IM departments of other domains. The small number of 176 participants is mitigated by repeating the survey after one year.

Conclusions and Future Work

This article has investigated the status quo of IM in German hospitals in five dimensions. It shows that IM departments have a reliable foundation but have potential for improvement in IT-process-framework usage and a better utilization of application systems for IM functions. Future works include the analysis of more dimensions that characterize IM in a further study. Also the IM department's professionalism correlated to its outcome and success needs to be evaluated in a further study based on existing data. The IM department's success comprises support for processes, satisfaction of users and hospital management, and IT costs. In a combination with the health IT report, the success factors and dimensions D1-D5, which characterize the IM department, could be linked with each other. We also need to understand, how the IM changes over time and which future challenges in IM can emerge.

[6] Participants could win a license for the enterprise modeling tool 3LGM2 , http://www.3lgm2.de/

Acknowledgments

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Beitrag 5: Investigating the Roots of Successful IT Adoption Processes - an Empirical Study Exploring the Shared Awareness-knowledge of Directors of Nursing and Chief Information Officers

Titel	Investigating the Roots of Successful IT Adoption Processes - an Empirical Study Exploring the Shared Awareness-knowledge of Directors of Nursing and Chief Information Officers
Autoren	Jan-David Liebe Jens Hüsers Ursula Hübner
Publikations-organ	BMC medical informatics and decision making
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Tabelle 6. Überblick Beitrag 5

Investigating the roots of successful IT adoption processes - an empirical study exploring the shared awareness-knowledge of Directors of Nursing and Chief Information Officers

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Abstract

Background: The majority of health IT adoption research focuses on the later stages of the IT adoption process: namely on the implementation phase. The first stage, however, which is defined as the knowledge-stage, remains widely unobserved. Following Rogers' Diffusion of Innovation Theory (DOI) this paper presents a research framework to examine the possible lack of shared HIT awareness-knowledge, i.e. an information gradient, of two crucial stakeholders, the Chief Information Officer (CIO) and the Director of Nursing (DoN). This study shall answer the following research questions: (1.) Does this gradient exist? (2.) Which direction does it have? (3.) Are certain HIT attributes associated with a potential gradient? (4.) Which determinants of diffusion go along with this gradient?

Method: Results of two surveys that focused on the topic "IT support of clinical workflows" from the viewpoint of CIOs and DoNs with corresponding datasets from 75 hospitals were used in a secondary data analysis. The gradient was operationalised by measuring the disagreement of CIOs and DoNs on the availability and implementation status of 29 IT functions. HIT attributes tested were relevance and novelty of the IT functions, determinants of diffusion were "combined project-leadership of IT staff and clinicians" and "ratio of IT employees to nurses".

Results: The analysis revealed a significant disagreement on the availability of 9 out of 29 HIT functions. In 23 HIT functions, the CIOs reported a higher implementation status than the DoNs, which points to a trend for a unidirectional gradient. The disagreement was significantly lower when the relevance of the IT function was high. Both determinants of diffusion correlated significantly negative with the degree of disagreement.

Conclusion: This is the first study to empirically examine shared awareness-knowledge of two IT-stakeholders that are crucial for triggering IT adoption on the frontline level in hospitals. It could be shown that a gradient and thus a lack of shared awareness-knowledge existed and was associated with certain factors. In conclusion, hospitals should implement improved cooperation between IT staff and clinicians and IT service density when establishing the prerequisites for successful IT adoption processes.

Keywords: IT adoption, IT diffusion, awareness-knowledge, IT stakeholder, Chief Information Officer, Director of Nursing

1 Introduction

1.1 Awareness-knowledge as a blind spot in IT adoption research in healthcare

IT adoption in healthcare has been studied increasingly in the recent decade [1,2,3,4,5,6,7]. Different concepts regarding the process of adopting health information technology (HIT) have been applied (e.g. deployment, assimilation, implementation, routinisation) [1,4,5,9]. Most of them are inspired and guided by Rogers' Diffusion of Innovation[1] Theory (DOI). The adoption process for individuals is traditionally presented in five stages: awareness, persuasion, decision, implementation, and confirmation [9]. Even though this linear model can be applied for complex healthcare organizations [10,11], there is strong evidence that organizations move back and forth between the adoption stages and thus follow a recursive path during adoption [1,8]. Furthermore, there are indications that different adoption processes exist on different levels of organisational decision-making (strategic, operational and frontline[2]) [13]. The strategic level is regarded most crucial for the successful adoption of HIT during the pre-implementation stage, i.e. the decision for the right investment in HIT that is aligned with strategic goals [11,13,14,15,16]. In later stages successful adoption of HIT depends more strongly on processes at the operational and frontline level, especially on the fit between individual users, technology and clinical tasks and processes [13,15,17].

Even though these findings are crucial for understanding how HIT innovations become finally accepted and used, most studies bypass a fundamental stage of IT adoption on higher levels of organizational decision-making: the knowledge-stage. Rogers (2003) divides this stage into three separate knowledge types: awareness-knowledge, how-to-knowledge and principle-knowledge. Awareness-knowledge occurs when an adoption unit becomes aware of an innovation's existence. The other two knowledge types contain information on how to use the innovation and how and why it works [9]. Among the three knowledge types, awareness-knowledge of major stakeholders is the bottleneck of the adoption process, in particular in complex organizations. Only if key decision makers gain and share awareness-knowledge about HIT innovations, adoption can proceed in either linear or recursive processes.

Awareness-knowledge, as part of Rogers' model of the adoption-decision process, is theoretically associated with three main components of the DOI theory: the adoption-unit, the diffusion and the innovation [18]. In order to investigate how awareness-knowledge is acquired and shared in healthcare organizations it is therefore important (1) to identify the units of adoption whose awareness-knowledge is most crucial, (2) to determine key attributes of HIT innovations which facilitate awareness-knowledge and (3) to find determinants of diffusion which particularly affect the acquisition and sharing of awareness-knowledge.

1.2 Awareness-knowledge of crucial decision making units

Adoption research very often focused on simple innovations for which the unit of adoption is the individual and adoption occurs by simple imitation [8,9]. In complex healthcare organizations the adoption-decision by individuals on the frontline-level is rarely independent of other decisions so that the unit of adoption is rather a team, a group of professionals, a department or an entire organi-

[1] According to Rogers' DOI theory innovations are defined as relative with regard to the adoption unit [9], i.e. a product is defined a innovative if it is new for the adopter.

[2] Other authors, e.g. Winter and colleagues [12] distinguish between strategic, tactical and operational levels, which correspond roughly with the above classification.

sation [8]. Therefore representatives of these social networks, who typically work on the strategic or operational level, will execute the actual adoption-decision for HIT innovations [11,14,15]. Only if these decision-making units (DMU) [9,19] gain awareness-knowledge they will initiate the adoption processes on the frontline level. The way these decisions are executed is highly influenced by the hierarchy of the networks and may be either contingent (dependent on decisions made by someone else), collective (the individual has a "vote" but ultimately must acquiesce to the decision of the group) or authoritative (the individual is simply told whether or not to adopt it) [8,9].

As HIT innovations require technical and clinical knowledge to be adopted successfully [1], clinical as well as IT professionals are crucial DMUs on the strategic and operational level [15]. Several studies provide evidence for the positive effect of the involvement of clinical leaders in the process of HIT innovation adoption [e.g. 13]. Geibert for example stated that nurses are more often involved in the early stages while physicians join during later phases [19], which proves the crucial role of nurses represented by the directors of nursing (DoN). The chief information officer (CIO[3]) acts both on the strategic level, i.e. to align organizational strategies with technical solutions [20], as well as on the operational level, i.e. to support the practical realisation of the IT concepts.

1.3 Attributes of HIT innovations that facilitate the creation of awareness-knowledge

Many studies support the notion of key attributes of innovations explaining a great amount of the variance in their adoption rates [8]. Standard attributes that are often cited are relative advantage, compatibility, complexity, trialability and observability [8,19,21].

Another attribute of HIT innovations, which might facilitate the acquisition of awareness-knowledge, is task issue [8], i.e. the relevance of the innovation for the adopting group to perform certain tasks. Although the question is still not answered whether need follows awareness or the other way around [9], there is evidence that the relevance for the potential adoption-unit, e.g. group of professionals or department, and furthermore the fit between the technology, the adoption-unit and the clinical tasks facilitates adoption [7,17], which includes the acquisition of awareness-knowledge.

The number of adopters of a specific technology itself may have a positive influence on the visibility of the technology within the community and hereby may become a crucial attribute for the acquisition of awareness-knowledge. This phenomenon is reflected by the first half of Rogers' bell shaped adoption curve [9]. The more adopters there are the higher is the increase in adoption. This trend is attenuated after the point of inflection, i.e. the first 50% of adopters. From there on the number of adopters obviously only plays an inferior role in adoption.

1.4 Determinants of the diffusion that facilitate the acquisition and sharing of awareness-knowledge

Diffusion is the process by which single adoption-units spread innovations through different communication channels among other members of a social network [9]. There are different cultural and structural determinants that were found to particularly influence the acquisition of awareness-knowledge. Probably the strongest determinant on diffusion is interpersonal influence through social networks, which is defined as the pattern of advice and communication among members of a social

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[3] For reasons of simplicity we speak of CIOs to denote persons who are responsible for the IT systems in the organisation. We are aware of the fact that these persons often are not called CIOs and do not possess the power a typical CIO should exert.

network [8,22]. Collaborative relationships between clinical- and IT professionals on the strategic and operational level were found to help building shared knowledge about HIT innovations [8,13,23]. Interactions can be facilitated in informal ways with the help of boundary spanners and champions [21] or in formalized ways through cooperative projects [1,11,12,24].

Another determinant of diffusion that will facilitate the acquisition and sharing of awareness-knowledge of HIT innovation is the network structure within and beyond the adoption-units, especially in multifaceted, highly fragmented healthcare organizations where many different groups use various technologies [1]. Different professional groups have different types of social networks, which influence the diffusion and the way awareness-knowledge is cascaded through the organisation. Whereas physicians tend to operate in informal, horizontal networks, nurses rather have formal, vertical networks [8,25]. A number of studies found evidence for a strong connection within professional groups and weak across them, which in turn leads to successful diffusion within certain adoption-units but slow diffusion across them [e.g. 26]

Besides interpersonal influence and network structure the number of IT specialists – relative to the size of the organisation – may also effect the acquisition and sharing of awareness-knowledge. If there are sufficient IT experts available communication between clinicians and IT staff members is easier and allows the clinicians to better access knowledge, new ideas and technical expertise, which then facilitates the adoption of HIT innovations [27].

1.5 Research Framework

Shared awareness-knowledge of key DMU on the strategic and operational level is a fundamental stage of HIT innovation adoption in complex healthcare organizations. Only if clinical and IT professionals, who are in the position of key DMUs, gain and share awareness-knowledge they will initiate IT adoption on the frontline level. As the literature had shown different determinants of diffusion and attributes of the HIT innovation can influence the acquisition and sharing of awareness-knowledge. At the same time, a lack of shared awareness-knowledge might become a powerful barrier that counteracts successful IT adoption.

Following these findings we propose a research framework in which we hypothesise that a gradient exists between the awareness-knowledge of technical and clinical key DMUs in complex healthcare organizations and that this gradient is associated with determinants of diffusion and attributes of the HIT innovation.

If the gradient is zero there is shared awareness-knowledge, which marks the ideal state (Fig. 1 Case1). If there are differences of awareness-knowledge within the two professions, the key DMUs, the gradient deviates from zero and the gradient deflects to either side (Fig. 1 Cases 2 and 3). Thus agreement between the two groups denotes shared awareness-knowledge, whereas disagreement indicates a lack of shared awareness-knowledge and goes along with either a positive or negative gradient. This system of balance and imbalance is affected by determinants of diffusion and attributes of the HIT system. These factors can act as facilitators or barriers to shared awareness-knowledge (Fig. 1 green and red arrows).

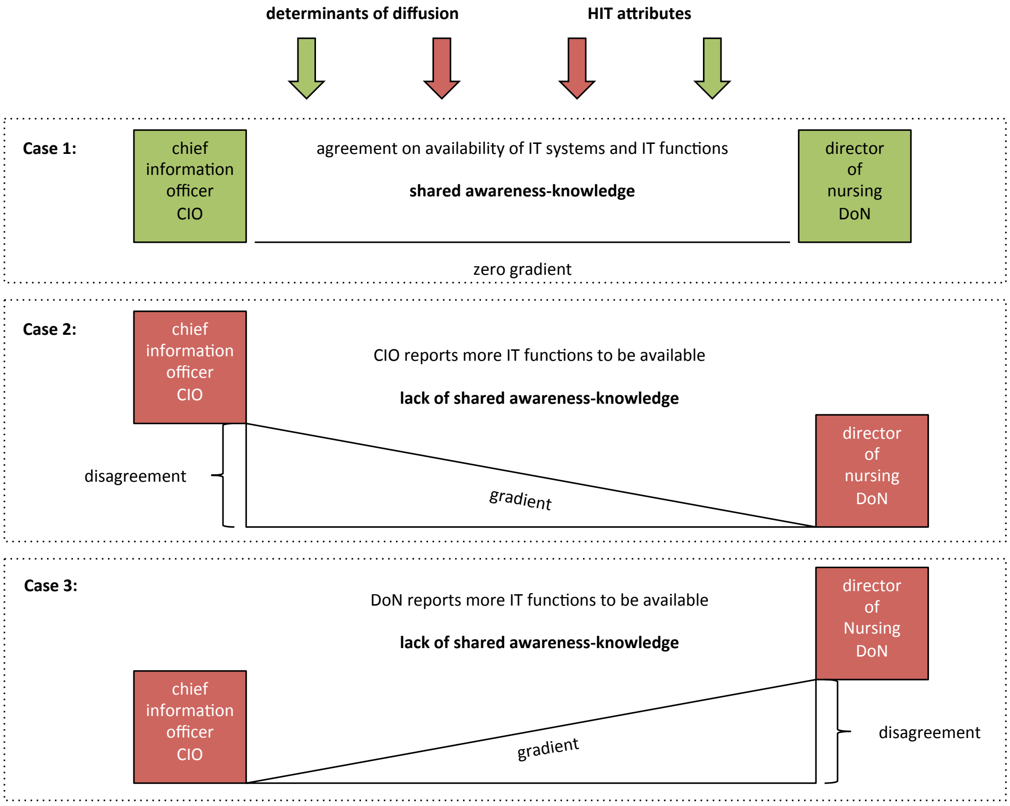

Figure 1. Research Framework

This study shall answer the following research questions:

(1.) Is there a gradient between the CIOs' and DoNs' awareness-knowledge?

(2.) Is this gradient uniform from CIOs to DoNs respectively vice versa or does the direction of the gradient vary?

(3.) Are there functions with certain HIT attributes that are associated with a lower or higher gradient?

(4.) Which determinants of diffusion go along with this gradient and is there an interaction between determinants of diffusion and HIT attributes?

Method

2.1 Data

In order to answer the research questions, an already existing dataset, which was captured in two separate surveys, was analysed [29,30]. Both surveys focused on the topic "IT support of clinical workflows": the first from the perspective of the CIOs, and the second from the DoNs. The surveys utilised one questionnaire with questions shared by both groups and a section that was specific to each group. The common items covered the IT availability (especially of IT functions). The specific section included structural and managerial determinants. The questionnaires were made available online utilising Unipark and sent to 1.317 CIOs and 1.754 DoNs in German hospitals in 2013 via e-mail. These persons had been identified as CIOs or other persons in charge of IT and as directors of nursing in a manual search based on all 1996 hospitals in Germany [31].[4] The response rate for the CIO survey was 19.7% (n=259) and for the DoN survey 26.5% (n=464). Two variables, the number of nursing staff and the number of organisational units were collected via secondary analyses. Table 1 presents the items that were considered in this study.

We studied the gradient of awareness-knowledge between CIOs and DoNs by measuring the disagreement over the existence and implementation status of 29 IT functions. These 29 IT functions of a HIT system cover many IT applications in a hospital of different types. They were adapted from the list of functions published by Jha and colleagues [28]. Attributes of IT functions considered were novelty (new vs. old) and relevance for nursing (nursing-relevant vs. non-nursing-relevant).

Finally we choose interprofessional teamwork and IT service density as determinants of diffusion. Interprofessional teamwork was measured by the categories “combined project-leadership (IT staff and clinicians)” versus “exclusive project-leadership of IT staff” or “exclusive project-leadership of clinicians” and IT service density by the “ratio of IT employees to nurses”.

Table 1. Type, number, examples, and response categories of the items shared by both groups.

type of item	number of items	example	response categories
IT functions	29	Is there a system for clinical reminders in your organisation?	- available in at least one unit - implementation started - no implementation - no response/I don’t know
inter-professional teamwork	3	Is there a combined project-leadership of IT staff and clinicians?	- yes - no
IT service density	1	Ratio of IT employees to nurses	- percentage

2.2 Matching of data sets

As both surveys were conducted separately and the questionnaires were anonymised, hospitals in which both professional groups had participated had to be identified and the respective data sets had to be matched. The identification of organisations with the participation of both groups was rule based and followed the scheme that CIOs and DoN had to provide identical answers in three demographic questions, i.e. postcode, ownership, and hospital type whereby the postcode had to be identical before the other two characteristics were checked. The results were inspected for quality and plausibility by three persons independently. Finally, 75 hospitals were identified that met the criteria. Cases with missing values from at least one professional group were generally discarded with regard to this item. In case participants had actively ticked “no response” this answer was counted as a valid

[4] In case the CIOs were responsible for more than one hospital, they were asked to answer for the hospital that was the most representative for this group of hospitals.

value in the sense of "I don't know", because it can reveal a lack of information flow in either direction.[5]

2.3 Analysis of the gradient between CIOs and DoNs

To test for a gradient between the awareness-knowledge of CIOs and DoNs the data were analysed in a stepwise manner starting with a highly condensed parameter, drilling down to the item level and single frequencies (Tab 2). For all analyses, the gradient was operationalized by the strength of disagreement between the reported implementation status of IT functions by CIOs and DoNs.

In a first step, the analyses were based on scores that summarised the number of IT functions reported to be available by the CIO and by DoN. Group-means between the two professional groups were tested for significance by paired t-tests. In a second step, different IT functions were studied separately. The implementation status as judged by the two professional groups was compared individually for each IT function to give a rough impression about the potential differences between the two professions. Group differences were tested for significance using the Wilcoxon-test and alpha was set to 0.05. In order to adjust for alpha inflation through multiple testing, the Bonferroni correction was applied. To further display the strength of disagreement the judgments of the CIOs and DoN were visualised in contingency tables (one per IT function) (Fig. 2). The judgments of the CIOs were placed in the horizontal direction and those of the DoNs in the vertical direction. Therefore, the lower triangular matrix (Fig. 2 dark grey cells) displayed the frequencies of judgments where the CIOs reported a higher implementation status and the upper triangular matrix (Fig. 2 light grey cells) displayed the frequencies of judgments where the DoN reported a higher implementation status. The relative strength of the total disagreement (non-directional disagreement) per IT function was calculated by adding the frequencies of the lower triangular matrix and these of the upper triangular matrix and by dividing this sum by the number of answers.

2.4 Analysis of the direction of the gradient

Information about the direction of disagreement was gained from computing the difference between the lower and the upper triangular matrix per IT function. A negative value indicated a higher implementation status reported by the CIOs, whereas a positive value indicated a higher implementation status reported by the DoNs. The sign and the magnitude of the difference divided by the number of answers presented the relative strength in which the disagreement tended into one direction (directional disagreement).

2.5 Analysis of the gradient with regard to HIT attributes

Four scores were calculated to test if the disagreement differentiates between certain groups of functions, i.e. an disagreement-score for (1.) new functions, (2.) old functions, (3.) nursing-related functions and (4.) non-nursing-related functions. The classification of new and old functions followed Rogers' innovation adoption curve [9]. Functions that where implemented in less than 50.0% of the German hospitals (equivalent to the Rogers' groups: innovators, early adopters, early majority) be-

[5] The category "no response" can be interpreted in three possible ways: (1) retention for providing further information, (2) semantical difficulties in understanding the question and (3) "do not know". As all participants provided information about the implementation status of at least 10 functions and as the wording of all questions was similar, we assumed that ticking "no response" could not be interpreted as the first two possibilities. Therefore in these cases we interpreted "no response" as "do not know".

longed to the category "new functions", and all other functions fell in the category "old functions" (equivalent to the Rogers' groups: late majority and laggards) [29]. [6]

- *New functions* comprehended the nursing documentation, medication loop, intensive care record, medical guidelines, clinical reminders, clinical alerts, decision support drug therapy, drug administration record, pharmacy, patient identification, critical incidents reporting system, electronic archive, health information exchange.
- *Old functions* were the medical summary, minimum medical data set, surgery record, anaesthesia record, order entry laboratory, order entry radiology with images, order entry radiology without images, order entry electrophysiology, specimen identification, materials management, medication order entry, meal ordering, inpatient management, outpatient management.

Six experts (three scientists in nursing informatics and three scientists in medical informatics) classified the 29 IT functions into nursing-related and non-nursing-related functions.

- *Nursing-related functions* comprised the nursing documentation, intensive care record, order entry laboratory, clinical reminders, clinical alerts, specimen identification, drug administration record, surgery record, anaesthesia record, patient identification, critical incidents reporting system, materials management, medication order entry, meal ordering, inpatient management, outpatient management, health information exchange.
- *Non-nursing-related functions* included the medical summary, minimum medical data set, medication loop, decision support drug therapy, pharmacy, order entry radiology with images, order entry radiology without images, order entry electrophysiology, medical guidelines, electronic archive.

Each disagreement score expressed the percentage of disagreement between CIOs and DoNs on the availability of IT functions in their hospital (coded as available or not). If - for example - the CIO and the DoN disagreed on the availability of 8 out of the 17 nursing-related functions, the disagreement score for the regarding hospital amounted to 47,1%. A paired t-test was performed to determine if significant differences between the contrastive pairs existed, e.g. new vs. old functions.

2.6 Analysis of the gradient with regard to determinants of diffusion

In order to test if determinants of diffusion could explain the gradient, three items that described the organisational management and one item that describes the organisational structure were correlated with the disagreement scores for all functions, nursing- and non-nursing-related functions, new and old functions and tested for significance with alpha set to 0.05. To operationalise the managerial determinants the following items where used (1) combined project-leadership of IT staff and clinicians (yes/no), (2) exclusive project-leadership of IT staff (yes/no), (3) exclusive project-leadership by clinicians (yes/no). The structural determinant was operationalized by the ratio of IT employees to nurses. A potential interaction between HIT attributes and determinants of diffusion was tested by correlating the disagreement scores of old versus new and nursing-related versus non-nursing related IT functions with the managerial and structural determinants, which represented the determinants of diffusion.

[6] Product identification and location identification were not considered for the disagreement scores due to missing values.

2.7 Overview of research questions and methods

Table 2 provides an overview of the different steps of analysis and their relation to the research questions.

Table 2. Overview of the steps of analysis in relation to the research questions.

research question	Steps of analysis
Is there a gradient between the CIOs' and DoNs' awareness-knowledge?	(1.) Comparison of group-means for the reported number of available IT functions regarding the CIO and the DoNs using a paired t-test. (2.) Comparison of group-means/ranks between the two professional groups on the level of IT functions using the Wilcoxon-test. (3.) Visualisation of the relative strength of disagreement via contingently tables for each IT function. (4.) Calculation of the relative strength of the non-directional disagreement for each IT function.
Is this gradient uniform from CIOs to DoNs respectively vice versa or does this gradient vary?	(5.) Calculation of the direction of disagreement between CIOs and DoNs for each IT function. (6.) Calculation of the relative strength of directional disagreement between CIOs and DoNs for each IT function.
Are there certain HIT attributes that are associated with a lower or higher gradient?	(7.) Categorisation of IT functions according to relevant HIT attributes and calculation of disagreement scores for each type of IT functions. (8.) Testing for significant differences of the disagreement scores between different types of IT functions - classified by the relevant HIT attributes - using a t-test.
Which determinants of diffusion go along with this gradient and is there an interaction between determinants of diffusion and HIT attributes?	(9.) Computation of Pearson correlations between the disagreement scores for all IT functions respectively for each type of IT function and three managerial and one structural item that represent determinants of diffusion.

Results

3.1 Participating Hospitals

The sample contained 75 hospitals of all types of ownership and size. Table 3 gives an overview of the hospitals in this study and their characteristics "ownership" and "size".

Table 3. Ownership and size of hospitals in the sample (n=75).

Hospital demographics	Absolute frequencies	Relative frequencies in %
Ownership: private hospitals	13	17.3%
Ownership: public hospitals	62	82.7%
Size: up to 399 beds	46	61.3%
Size: 400 to 799 beds	19	25.3%
Size: 800 and more beds	10	13.4%

3.2 Existence and Direction of a Gradient

The average number of IT functions available reported by the CIOs was 17.5 (SD ±5.3). The DoN reported an average of 14.4 (±3.9) IT functions available. The two groups differed by about three IT functions, which was significant in the paired t-test (p <0.00).

Table 4 shows the result of the Wilcoxon-test and summarised frequencies of the contingency tables (example see figures 2). Out of 29 IT functions, there were nine with significant differences in the judgment of the implementation status. Column two presents the relative strength of the non-directional disagreement, which varies between 73.6% for *clinical reminders* as the highest non-directional disagreement and 16.4% for *order entry laboratory* as the lowest non-directional disagreement. In total, 14 IT functions showed a non-directional disagreement of 50.0% and more. Column three presents the relative strength of the directional disagreement. A negative difference was calculated for 23 functions, which indicates a higher implementation status reported by the CIOs. This disagreement showed an absolute value of 20.0% and more for 13 IT functions. The strongest disagreement where CIOs reported a higher implementation status concerned *order entry radiology without images* (-47.7%). The strongest disagreement in the other direction was related to *medical guidelines* (+12.4). Column four presents the relative frequencies of the upper triangular matrix where the DoNs reported a higher implementation status and column five presents the relative frequencies of the lower triangular matrix where the CIOs reported a higher implementation status.

DoN \ CIO	implementation in at least one unit	implementation started	no implementation	I don't know	total
implementation in at least one unit	8	7	7	2	24
implementation started	4	7	8	3	22
no implementation	5	4	8	2	19
I don't know	4	2	1	0	7
total	21	20	24	7	72

Figure 2. Contingency table of the IT function medical guidelines (n=72)

Table 4. Direction and strength of disagreement for the individual IT function (bold: significant after Bonferroni correction).

	(a)	(b)	(c)	(d)
IT functions for supporting…	non-directional relative strength of disagreement (c+d) in %	direction and relative strength of disagreement (c-d) in %	sum of relative frequencies upper triangular matrix (DoN) in %	sum of relative frequencies lower triangular ma-trix (CIO) in %
order entry radiology without images (n=67)	62.7%	-47.7%	7.5%	55.2%
health information exchange (n=71)	60.6%	-32.4%	14.1%	46.5%
outpatient management (n=73)	34.2%	-23.4%	5.4%	28.8%
inpatient management (n=72)	23.6%	-20.8%	1.4%	22.2%
intensive care record (n=75)	54.7%	-25.3%	14.7%	40.0%
specimen identification (n=70)	41.4%	-21.4%	10.0%	31.4%
order entry electrophysiology (n=74)	39.2%	-23.0%	8.1%	31.1%
order entry radiology with images (n=73)	34.2%	-17.8%	8.2%	26.0%
nursing documentation (n=75)	44.0%	-22.6%	10.7%	33.3%
anaesthesia record (n=75)	38.7%	-17.3%	10.7%	28.0%
minimum medical data set (n=75)	30.7%	-20.1%	5.3%	25.4%
medication order entry (n=75)	46.7%	-17.3%	14.7%	32.0%
medical summary (n=75)	21.3%	-15.9%	2.7%	18.6%
product identification (n=72)	65.3%	-29.1%	18.1%	47.2%
surgery record (n=55)	20.0%	-16.4%	1.8%	18.2%
critical incidents reporting system (n=67)	61.2%	-28.4%	16.4%	44.8%
order entry laboratory (n=73)	16.4%	-8.2%	4.1%	12.3%
materials management (n=72)	37.5%	-12.5%	12.5%	25.0%
location identification (n=72)	61.1%	-24.9%	18.1%	43.0%
patient identification (n=72)	54.2%	-7.0%	23.6%	30.6%
clinical reminders (n=72)	73.6%	-20.8%	26.4%	47.2%
decision support drug therapy (n=72)	63.9%	-5.5%	29.2%	34.7%
pharmacy (n=70)	38.6%	+1.4%	20.0%	18.6%
medical guidelines (n=72)	68.1%	+12.5%	40.3%	27.8%
drug administration record (n=72)	61.1%	+2.7%	31.9%	29.2%
medication loop (n=72)	63.9%	+8.3%	36.1%	27.8%
clinical alerts (n=72)	63.9%	-2.7%	30.6%	33.3%
meal ordering (n=72)	22.2%	+2.8%	12.5%	9.7%
electronic archive (n=72)	54.2%	+4.2%	29.2%	25.0%

3.3 Correlation of HIT attributes with gradient between CIOs and DoNs

All functions were classified by the HIT attributes novelty {old, new} and relevance {nursing related, non-nursing related}. The relative disagreement for new functions was slightly but not significantly higher than for old functions (2.3%; $p > 0.05$). For nursing related functions the relative disagreement was significantly lower than for non-nursing related functions (5.2%; $p < 0.05$).

Table 5. Group means (± SD) and association of the disagreement scores (in%) for different types of IT functions (n=75).

	new functions: mean (SD)	**old functions: mean (SD)**	**p-value**
disagreement score	29.9 (±17.9)	27.6 (±16.2)	0.262
	nursing-related functions: mean (SD)	**non-nursing-related functions: mean (SD)**	**p-value**
disagreement score	28.4 (±14.5)	33.6 (±15.2)	0.02

3.4 Correlation of determinants of diffusion with gradient and interaction between HIT attributes and determinants of diffusion

The correlation between the determinants of diffusion and the overall disagreement score, i.e. for all functions, was significantly positive in case of “exclusive project-leadership of IT staff” and significantly negative in case of “ratio of IT employees to nurses”. “Exclusive project-leadership of IT staff” also correlated significantly positive with “non-nursing-related functions”, whereas there was no other significant correlation of the “ratio of IT employees to nurses” with any other type of IT functions described by HIT attributes. There was a significant negative correlation between “combined project-leadership (IT staff and clinicians)” with the disagreement score for new functions showing an interaction between these specific categories of interprofessional teamwork and novelty of functions. In the majority of the cases the sign of the correlations between the determinants of diffusion and the disagreement scores were identical with the exception of very low correlations, i.e. almost zero correlations. Thus determinants of diffusion were similarly associated with HIT attributes only showing variety in the strength of the correlation.

Table 6. Correlation-matrix for disagreement scores and different determinants of diffusion and HIT attributes (bold: sig *p< 0.05; ** p<0.001)

determinants of diffusion			disagreement scores for different HIT attributes			
			novelty		relevance	
		all functions	new	old	nursing-relevant	non-nursing-relevant
inter-professional teamwork	combined project-leadership (IT staff and clinicians)	-0.232	**-0.252***	+0.009	-0.075	-0.214
	exclusive project-leadership of IT staff	**+0.344****	+0.252	+0.192	+0.166	**+0.357****
	exclusive project-leadership of clinicians	-0.088	+0.091	-0.163	-0.092	-0,127
IT service density	ratio of IT employees to nurses	**-0.287***	-0.140	-0.212	-0.154	-0.225

Discussion

This study is based on the notion that recent IT adoption research in healthcare does not sufficiently consider the existence of shared awareness-knowledge of key decision makers in healthcare organizations. This finding is surprising as shared awareness-knowledge is the origin of the adoption process on the operative and frontline level of those organizations. Our analysis followed the hypothesis that a gradient between crucial stakeholders in the clinical and technical setting existed, and that this gradient appeared as a gap between the awareness-knowledge of the technical and clinical stakeholders. This study focuses on the DoN and on the CIO as they play a significant role at the beginning of the organisational IT adoption once the investment had been decided.

We matched two already existing datasets, which resulted in a sample of 75 hospitals of different size and ownership. For the purpose of this study, we used the responses of the CIOs and DoNs about the implementation status and availability of 29 IT functions.

The first research question investigated the fact if there existed a gradient between the CIOs and the DoNs with regard to awareness-knowledge. We found a significant disagreement between CIOs and DoNs concerning the number of IT functions available in their hospital. This result was also confirmed on the level of individual functions: CIOs and DoNs significantly disagreed on the implementation status of nine functions. Fourteen IT functions showed a total (non-directional) disagreement of 50% and more. In fact we found just one IT function (*order entry laboratory*) were the total disagreement between CIOs and DoN amounted to less than 20%. In conclusion to this research question, this study confirms the existence of a gradient.

The second research question asked if this gradient was uniform from CIOs to DoNs respectively vice versa or if the direction of the gradient varied. The comparison of the group means of the total number of IT functions revealed that the CIOs reported significantly more functions to be available than the DoNs. These results could be replicated on the level of individual IT functions: the CIOs reported a higher implementation status for 23 out of the 29 functions. We found the strongest directional difference for *order entry radiology without images* (-47.7%). Although there were IT functions for which the DoNs reported a higher implementation status than the CIOs the large majority of IT functions yielded a different picture and pointed to a trend for a uniform gradient. In almost all of these cases the difference was rather small with the exception of the IT function “medical guidelines”.

These results are not surprising as the CIOs were responsible for making these IT functions technically available. Yet they also confirm the assumption that technical availability does not automatically result into awareness on the side of the users, in particular in case of software functions, which are sometimes hidden in a complex user interface and become only obvious if the users are explicitly made aware of them. The interpretation of DoNs not being interested in IT and therefore not knowing the details seems rather unlikely because tkhe DoNs in our study participated in the survey by their own choice. The survey itself clearly addressed technical issues right from the beginning and could have been rejected immediately if no interest existed.

We also asked (third research question) whether there were functions with certain HIT attributes that are associated with a lower or higher gradient, stronger disagreement. Examining the results of the individual types of IT functions, new functions (e.g. *health information exchange* or *critical incidence reporting*) seemed to be more vulnerable for a strong directional disagreement than old functions, i.e. CIOs reported a higher implementation status than DoNs. On the other hand, nursing-related functions (e.g. *patient identification*) seemed to show a lower disagreement. To test for a systematic difference we calculated disagreement-scores for four groups of IT functions representing the two different HIT attributes “novelty” and “relevance” and compared group means of the two contrasting pairs old versus new functions and nursing-related versus non-nursing related functions. We found a higher disagreement on new IT functions than on old ones although this difference was not significant. For nursing-related functions the disagreement was significantly lower than for non-nursing-related functions. These results indicate that the kind of technology, i.e. the HIT attributes, can be an important barrier for shared awareness-knowledge – as in the case of the novelty of the IT function – or it can become a facilitator as in case of the relevance of the IT function. In particular the relevance of the technology for the daily work seems to be associated with a lower gradient. These results correlate with earlier studies, which found technologies to be easier adopted if they were relevant to the performance of the intended user’s work [32].

The fourth and final research question was if determinants of diffusion went along with a lower gradient and if there was an interaction between determinants of diffusion and HIT attributes. We therefore computed correlations between two determinants (interprofessional teamwork and IT service density) and the disagreement between CIOs and DoNs. We hypothesised that interprofessional teamwork, i.e. combined project-leadership of IT staff and clinicians, and higher IT service density, i.e. higher ratios of IT employees to nurses, facilitated shared awareness-knowledge and thus went along with less disagreement on the availability of IT functions. Our results support this assumption. If hospitals exercise a combined project-leadership the disagreement between CIOs and DoN on the availability of new functions is significantly lower. This finding is supported by other studies, which found inter-professional teamwork and the involvement of clinicians in management networks to foster adoption especially of new technologies as these conditions can enable “the development of shared meanings and values in relation to the innovation” [8, p. 606]. In contrast to these results, “exclusive project-leadership of IT staff” correlated significantly positive with disagreement on the availability on all IT functions and on non-nursing related IT functions. This indicates the lack of user involvement. Regarding the determinants of diffusion we further hypothesised that shared awareness-knowledge depended on service density, which was operationalised by the ratio of IT employees to nurses. As expected, hospitals with a low ratio of IT employee to nurses tended to have higher disagreement scores and vice versa. These results correspond with prior studies [e.g. 33] which indicated that the number of IT employees seems to be crucial not only for later stages of the IT adoption process but also for the awareness-knowledge phase.

Limitations

The analysis included 75 hospitals, which is a rather small sample even though it represented hospitals of all size categories and types of ownership.

When studying determinants of diffusion and HIT attributes as facilitators or barriers, it is desirable to draw conclusions in terms of the influence of these factors or the mechanism of action. We, however, computed correlations, which do not give proof of any influence but only of co-existence. The correlations found were small and thus the results need to be replicated and more determinants of diffusion (e.g. strategic alignment, user-training) and more HIT attributes (e.g. software versus hardware) should be tested.

We focused on shared awareness-knowledge respectively on the lack of it and we studied some determinants of diffusion. What we did not measure explicitly is interpersonal communication, a powerful driver of shared awareness-knowledge. In our study setting, interpersonal communication served as a latent variable, which might be influenced by interprofessional teamwork and IT service density, but was not measured.

Future studies should investigate the transition from awareness-knowledge to frontline usage, the next step along the IT adoption process.

Besides the perspective of CIOs and DoNs, future research could also analyse shared awareness-knowledge of other professional groups, e.g. between CIOs and physicians.

Conclusion

This is the first study to empirically examine awareness-knowledge, particularly shared awareness-knowledge of two stakeholders that are crucial for triggering IT adoption on the frontline level in an organisation. The study proposes a research framework and investigates whether there is a hypothesised gradient between the two stakeholder groups and thus a gradient of awareness- knowledge. It also looks at factors, namely determinants of diffusion and HIT attributes that may influence this gradient. We identified facilitators and barriers of awareness-knowledge: Low IT service density and exclusive IT staff leadership in IT projects seem to impede the development of shared awareness-knowledge and to build up a gradient. In contrast, combined leadership in IT projects seems to facilitate shared awareness-knowledge and mitigate the gradient. None of these determinants of diffusion was significantly associated with the awareness-knowledge of old functions. In contrast, shared awareness-knowledge on new IT functions can benefit from combined IT project-leadership, thus from interprofessional teamwork. It can be concluded that awareness-knowledge of non IT stakeholders which underpins the adoption of new information technologies must not be taken for granted. It must be constructed and continually negotiated among all relevant groups. In hierarchical organisations, such as hospitals, shared awareness-knowledge of CIOs and DoNs is the gateway to adoption. Otherwise, often discussed determinants for successful IT adoption might not become effective. This should be taken into account in future IT adoption research. The practical conclusion is that hospitals should establish a combined leadership of IT experts and clinicians in IT projects and should raise the IT service density when establishing the prerequisites for successful IT adoption processes.

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Competing interests

The authors declare that they have no competing interests.

Authors' contributions

The three authors contributed directly to the planning, execution and analysis of the work reported. All three read and approved the final manuscript.

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Beitrag 6: Development and Evaluation of a Three-Dimensional Multi-level Model for Visualising the Work-flow Composite Score in a Health IT Benchmark

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Tabelle 7. Überblick Beitrag 6

Development and evaluation of a three-dimensional multi-level model for visualising the workflow composite score in a health IT benchmark

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Abstract

Background: Clinical information logistics is the backbone of care workflows inside and outside of hospitals. Due to the great potential of health IT to support clinical processes its contribution needs to be regularly monitored and governed. IT benchmarks are a well-known instrument to optimise the availability and use of IT by guiding the decision making process. The aim of this study was to translate IT benchmarking results that were grounded on a hierarchical workflow scoring system into an appropriate visualisation concept.

Methods: To this end, a three-dimensional multi-level model was developed, which allowed the decomposition of the highly aggregated workflow composite score into score views for the individual clinical workflows concerned and for the descriptors of these workflows. Furthermore this multi-level model helped to break down the score views into single and multiple indicator views.

Results: The results could be visualised per hospital in comparison to the results of organisations of similar size and ownership (peer reference groups) and in comparison to different types of innovation adopters. The multi-level model was implemented in a benchmark of 199 hospitals and evaluated by the chief information officers. The evaluation resulted in high ratings for the comprehensibility of the different types of views of the scores and indicators.

Conclusions: The implementation of the multi-level model in a large benchmark of hospitals proved to be feasible and useful in terms of the overall structure and the different indicator views. There seems to be a preference for less complex and familiar views.

Key words

IT benchmarking, Innovation benchmarking, Information visualisation, Data visualisation, Hierarchical visualisation, Multi-level model, Indicator views, Workflow composite score

1 Introduction

Complex and advanced health care processes, which require good communication among the health care professionals, on time exchange of the relevant patient data and their thorough analyses, cannot be performed without appropriate health IT systems [1-5]. The construct information logistics helps to better understand the nature of information flows between the different actors and hereby to ensure information continuity [6-9]. However, health information technology (HIT), *i.e.* the carrier of the information and enabler of information flows, is often regarded as a black box by executives. This happens because the mechanisms behind HIT systems frequently lack transparency and systematic approaches. In addition, valid models to regularly measure and evaluate IT performance and IT services are missing as well [5, 10]. Only when strategic methods for planning, monitoring and governing are implemented is IT optimisation possible [5, 11]. Benchmarking of HIT systems is regarded as a suitable method for managing IT in health care organisations on a strategic level [6, 12]. Benchmarking procedures can be classified into two groups: statistical benchmarks with a large number of participants and in-depth benchmarks in smaller and often closed groups of participants [13]. Benchmarking allows comparing equivalent structures, processes and methods within a single enterprise or a group of enterprises and according to the pure doctrine between an enterprise and the market leader in this or another industry [14-16]. In order for benchmarks to grasp the essence of HIT supported processes, the construct clinical information logistics has been proposed and targeted by benchmarks [17]. Clinical information logistics was measured by the workflow composite score (WCS) [18], which represented the most aggregated level within a hierarchical scoring system of single IT features (raw indicators), sub scores and finally the WCS. Due to its novelty, the WCS system has not been presented in an appropriate graphical form.

Besides measuring IT structure and IT process support, benchmarking can be employed to compare enterprises on the basis of external criterion ability and power to be innovative [19-21]. HIT can appear as an innovative product itself but can also enable process innovations, *i.e.* leveraging new processes or increasing the efficacy and efficiency of workflows [5]. Benchmarking organisations in terms of HIT innovations can thus investigate IT structures as well as IT support of clinical processes [22] and can classify the organisation according to well established groups of innovation adopters [23]. The innovation perspective broadens the scope towards developing the organisation by realising new opportunities through IT [5]. Still, classic benchmarks rather focus on costs, efficiency and efficacy less on innovation.

Due to its high potential, HIT benchmarks have become an area of interest in the recent years [24-28]. Despite this high interest, there is no explicit study – neither within nor outside healthcare – that proposes and evaluates a coherently structured visualisation system for indicators and scores. Therefore, the challenge was to implement the presentation of the benchmark results in a logical and understandable structure and thereby reflect a new highly aggregated indicator of clinical information logistics. Such system would help to meet the big challenges of communicating the benchmark results to members of the executive level. According to our understanding these challenges are:

- To select the most important and significant results flexibly from a wealth of results
- To present these results in a manner that is understandable for non IT experts
- To present the important results so that their messages can be captured within a short time span

Against this background, this study aims at developing and evaluating a visualisation system for benchmark results that could be used as an information base for discussions between chief information officers and (other) members of the executive level, *e.g.* chief executive officers, medical and/or nursing directors. This visualisation system should allow the analysis of large data sets and the processing of these data so that they become accessible, comprehensible and usable for the users of these data [29, 30]. In this sense, it also should visually establish links between the different scores and raw indicators, *i.e.* the IT features, among each other and towards the overall goal to represent clinical information logistics. The following research questions guided this study:

1) Which visualisation system allows the users to obtain an overview of the IT benchmarking results and at the same time provides enough details?
2) How can the scores and the raw indicators, *i.e.* the IT features, be represented in a graphical form so that individual results can be compared with the results of the peers in the reference groups?
3) How can measures of the innovative strength of an organisation be displayed graphically?
4) How do benchmark participants evaluate the visualisation of the raw indicators, *i.e.* the IT features, and the different scores?

2 Methods

2.1 Data collection and aggregation

The visualisation concept to be developed should be implemented in a benchmarking environment with real data. The data basis utilised was provided by a survey, which is conducted regularly in German hospitals, the IT Report Healthcare (www.it-report-healthcare.info) and which was used in the 2014 version [31]. The data basis consisted of 92 IT features [18], the so-called raw indicators, which were grouped in the categories IT functions, IT structure and IT support of clinical processes. These 92 IT features were allocated to four sample benchmark processes, *i.e.* ward rounds, pre-surgery processes, post-surgery processes and discharge and to the four descriptors data and information, IT functions, integration and distribution. Scores were computed on the level of the four processes and on the level of the four descriptors. The sum of these scores yielded the WCS. All data were statistically analysed using IBM SPSS V21 and Microsoft Excel. Thus a total of 92 features (raw data) per hospital had to be structured and aggregated before they could be visualised. We largely followed the process of data aggregation proposed by Card [32] (see Figure 1). To this end, the raw data were first internally organised in tables, which contained individual values and corresponding statistical parameters of the reference group. Then an overall visual access to the benchmark results, the visualisation system was devised from which particular views, the diagrams were deduced.

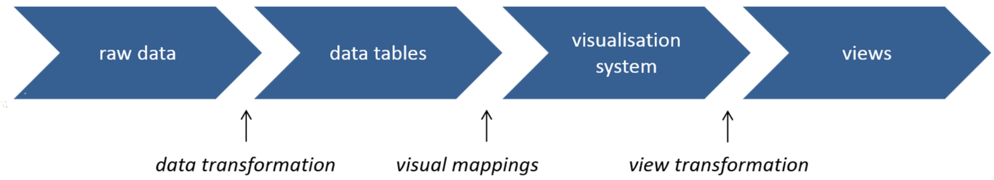

Figure 1. Data aggregation and transformation (following 32)

2.2 Reference groups

A total of 259 hospitals represented by their chief information officer took part in the survey [31]. A workflow composite score could be computed for a group of 183 hospitals, which provided enough details for the computation. Out of the 259 hospitals 199 participated in the IT benchmark and of which 156 hospitals were benchmarked based on the workflow composite score, which could be calculated for them. The other 43 hospitals out of the 199 were benchmarked on the basis of the raw indicators. In order to allow the comparisons, organisations of similar size and ownership were grouped [28] and statistical parameters within these groups were calculated. They formed the so-called peer reference groups. Table 1 shows the characteristics and numbers of the respective groups.

Table 1. Participants' structure of the IT benchmarking

Reference groups		Number of benchmark participants (WCS)	Size of peer reference group (WCS)	Number of all benchmark participants (raw indicators)	Maximum size of peer reference group (raw indicators)
Owner-ship	public	130	150	161	202
	private	26	33	38	57
Size	< 200 beds	33	38	59	81
	200 – 399 beds	48	60	55	77
	400 – 599 beds	33	39	36	43
	600 – 799 beds	16	16	20	22
	≥ 800 beds	26	30	29	36

In addition to these peer reference groups, innovation reference groups were formed according to the adoption categories of Rogers [23] and the organisations were classified as innovators, early adopters, early majority, late majority and laggards (see Figure 2) with regard to the WCS and individual raw indicators (IT features).

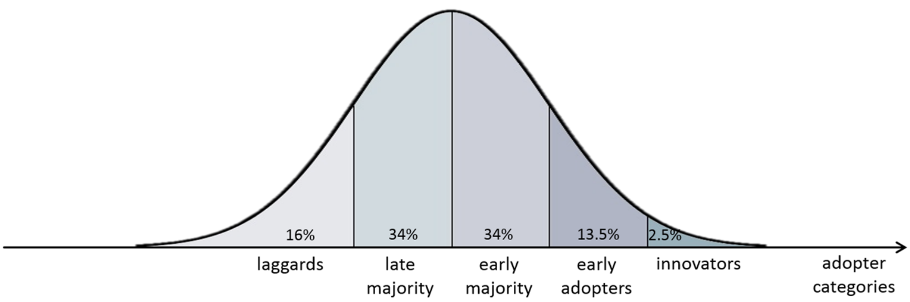

Figure 2. Adoption categories according to the Diffusion of Innovations model [23]

2.3 Information to be visualised

Based on the hierarchical scoring model. All scores and related IT features (raw indicators) composing the WCS had to be presented in an appropriate form. Table 2 gives an overview of the indicators to be visualised.

Table 2. Indicators to be visualised

Type of indicator	Content of indicator	Name of indicator
Composite score	composite score	workflow composite score
Sub scores	workflow scores	workflow score *ward round*
		workflow score *pre-surgery*
		workflow score *post-surgery*
		workflow score *discharge*
	workflow descriptor scores	workflow descriptor score *data and information*
		workflow descriptor score *functions*
		workflow descriptor score *integration*
		workflow descriptor score *distribution*
Raw indicator/ IT features	IT structures	architecture of health information system
		WiFi implementation
		workflow management system
		electronic devices for processing patient data
		electronic health record system
	IT functions	clinical documentation
		order entry and observation reporting
		clinical decision support
		patient safety
		supply chain functions
		interface functions
	IT processes	ward rounds
		• list of patient data available on desktop PC or on mobile device
		• access to patient data via desktop PC or mobile device
		pre-surgery processes
		• surgery planning
		• list of patient data available prior to surgery
		post-surgery processes
		• list of patient data available after surgery on normal ward or on intensive care unit
		• format of patient data to be transmitted to normal ward or intensive care unit
		discharge
		• reminders for pending activities before discharge
		• electronic systems for clinical pathways and medical guidelines
		• list of patient data available for medical summaries

	• electronic medical summaries • electronic nursing summaries

2.4 Development of the visualisation system

In order to answer the first research question, an overall framework had to developed that could encompass the entire hierarchical scoring model and make its structure transparent and understandable and at the same time allow individual comparisons within the reference group and with the best of the group. The challenge for constructing the visualisation system was less to find the best types of diagrams but rather to build a framework within which the users could navigate in a large dataset and could interact with the data [33]. Since the scoring system was hierarchical the visualisation system had to be constructed accordingly and had to follow a tree-structure [30, 34]. Hereby, the hierarchy defined the sequence of the presentations and the categories (clinical workflows and workflow descriptors) determined the content at each hierarchical level [34]. This drill-down procedure should allow the user to navigate within the dataset along a predefined scheme without getting drowned in a sea of information [35].

2.5 Principles of data visualisation applied in this study

The development of the visualisation system as such and of the different types of diagrams was based on the principles of information visualisation [29, 30, 33-39] and was guided by the goal "[…] to amplify cognition by the [...] visual representation of abstract data" [32]. The display of the data rested on general issues of information perception and interpretation as well as on issues of acceptance [30, 35, 36]. Against this background, principles of cognition and information representation (see Table 3) could be applied to developing the visualisation system (*e.g.* correct perception, compactness, comprehensibility) as well as to the different types of diagrams (*e.g.* saliency, compactness, differentiation).

Table 3. Principles of cognition and information representation [34, 40]

Principles of cognition / information representation	Explanation and application in this study
Correct perception	to support an appropriate understanding of the results.
Salience	to direct the attention to the most important information.
Compactness	to present pieces of information together, which belong together.
Similarity	to visualise similar information similarly.
Differentiation	to present information depending on the context, *e.g.* distinguishing between results of individual benchmark participant and these of the peers (reference group).
Comprehensibility	to ease the understanding of the results, *e.g.* by providing descriptions.

In order to provide enough flexibility and to allow different perspectives, identical information could be displayed in different types of diagrams [30, 33, 39, 41, 42] to enable the users to deliberately change their point of view. In addition to these principles of cognition and information representation, well-known design principles could be utilised for constructing the layout of the diagrams, *i.e.* colours in general [43], font [34, 43], background colours [34, 37, 43], highlights [29, 30, 33-35, 43], 2D visualisation [33, 43] and presentation of digits [30]. For example, the use of highlights could ease not only the perception but also facilitate the analysis of the data and help leading to appropriate actions [35].

2.6 Development of the views

The views on the benchmarking results should have a graphical format first and foremost but should also display briefings or profiles in tabular format [16]. Graphical formats should make use of well-known types of diagrams– if possible - in order to increase the recognition value and minimise the need to learn how to interpret the data [36]. Diagram styles should vary in order to maintain a high level of attention, however similar information should be coded in a similar style. Raw indicators should be presented either in groups of similar indicators (multiple indicator view), if they could be summarised by a topic (*e.g.* clinical documentation) otherwise they should be presented as single indicators. If multiple indicators were grouped different compositions of diagrams were built to allow different perspectives [39, 41, 42]. These perspectives were related either to the peer reference group, to the best of the group within the peer reference group or to the innovation adoption group.

2.7 Implementation of the visualisation system and the views

The visualisation system and the views were implemented in Microsoft Excel after importing the data and statistical parameters from a separate Microsoft Excel reference document (calculation results, individual results, statistical parameters). Statistical calculations and parameters were made in SPSS and Microsoft Excel. The output was realised in three ways: in terms of printouts of a benchmark brochure (short version) and electronic pdf prints (long version), which were semi automatically bundled (one per participant), as well as in terms of an interactive dashboard. Dashboards are well-known instruments to optimise processes, plans and strategies to present data in the best manner for decision-making [44]. Content and design elements of different types of dashboards [45] were implemented. By being able to represent different views side by side, the users could compare them and choose the one most appropriate for their purpose [39]. All views were annotated and had comprehensive legends.

2.8 Evaluation

In order to optimise the visualisation in future IT benchmarks, ratings of the comprehensibility of the views should be obtained from the benchmark participants. In addition, the utility of the workflow composite score was measured and correlated with the comprehensibility. This evaluation should be conducted in a comparable way as the evaluation of a previous IT benchmarking [28] to show the progress made. Comprehensibility was captured in four main questions with three corresponding sub questions related to the types of visualisation and the scores. A four point Likert scale was used with a codomain from very (comprehensible, helpful) to not (comprehensible, helpful) at all. The online questionnaire was sent to all benchmark participants.

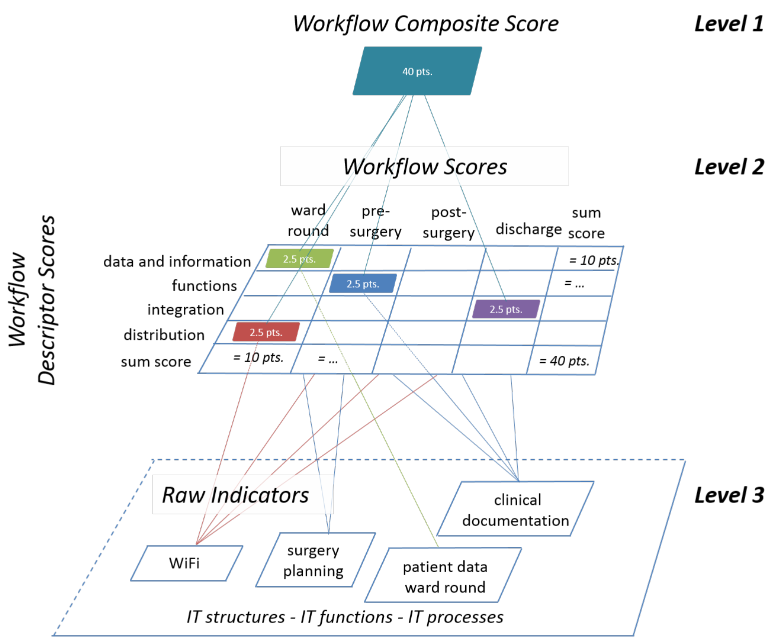

Figure 1. Schematic illustration of the three-dimensional multi-level model and its relationships

3 Results

3.1 Three-dimensional multi-level model as the visualisation system

In order to correspond with the hierarchical structure of the scoring system and to accommodate its scores and indicators we decided to construct a three-dimensional multi-level model (see Figure 3). The workflow composite score, the sum of all sub scores, resided at the top level (level 1). The workflow descriptor scores and the workflow scores constituted the next level (level 2). This level was defined by the four workflow descriptor scores (data and information, functions, integration and distribution) as the one axis and the four workflow scores (ward rounds, pre- and post-surgery processes, discharge) as the other. This scheme divided level 2 into a grid of 16 independent cells with each cell containing a maximum value of 2.5 points. The sums per workflow (maximum of 10 points) or per workflow descriptor (maximum of 10 points) appeared at the rim of this level in eight additional cells so that the total of cells was 24. The sum of these cell values constituted the WCS, which could reach 40 points at maximum. All 92 raw indicators, the IT features describing the IT structure, the IT functions and the IT processes, resided at level 3. The multi-level model made the relationship between level 2 and level 3 transparent and showed which raw indicators contributed to which cells at level 2 (see Figure 3).

The three-dimensional multi-level model was presented to the benchmark participants in a hierarchical way as depicted in Figure 4.

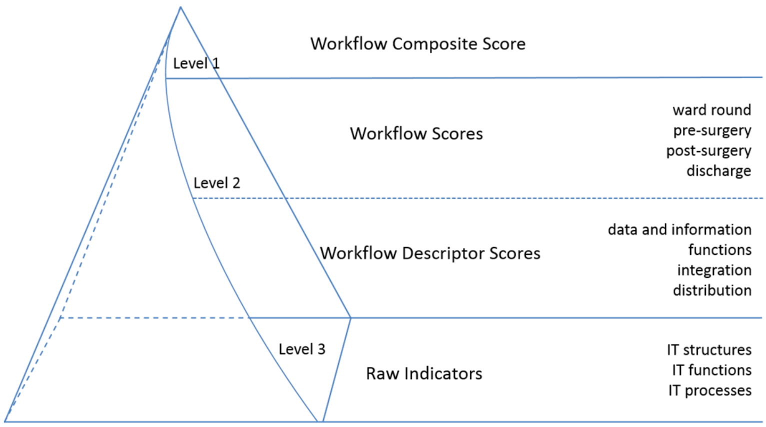

Figure 2. Visualisation of the multi-level model

3.2 Views on all levels of the three-dimensional multi-level model

3.2.1 Level 1

The WCS was graphically depicted as a composite score innovation view (see Figure 5), which was developed for the purpose of this benchmark and had not been used before. This view combined information about the peer reference group and about the categories of innovation adopters according to Rogers' Diffusion of Innovations model, which segments the distribution of a certain score into the five categories: innovators (2.5%), early adopters (13.5%), early majority (34%), late majority (34%) and laggards (16%) [23]. The distribution of the WCS values was related to the peer reference group. As there were two criteria to build the reference groups, *i.e.* number of beds and ownership, two composite score innovation views per WCS could be produced. Innovation categories were coded by colour and the individual value of the benchmark participant was shown as a vertical bar with the exact WCS value annotated.

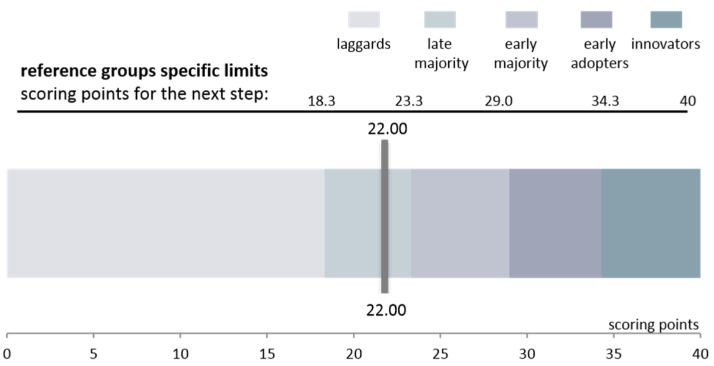

Figure 5. Composite score innovation view – workflow composite score (WCS)– public hospitals (n = 150)*

The composite score innovation view required the score values to be distributed symmetrically, *i.e.* approximately normally distributed, so that the Rogers adopter categories were appropriate. As the WCS met these requirements [18], this type of view could be utilised.

3.2.2 Level 2

At the level of the sub scores, the values were not normally distributed so that this innovation view was not appropriate. We therefore developed a view for these sub scores that segmented the distribution of the score values into two areas within each peer reference group. These two areas corresponded with the combined three categories innovators (2.5%), early adopters (13.5%), and early majority (34%) on the one hand and with the two categories late majority (34%) and laggards (16%) on the other. Statistically speaking, the distribution was split into two halves by the median. We called this view simple score innovation view (see Figure 6). A vertical bar denoted the individual value of the hospital. It was applied for all workflow scores and all workflow descriptor scores. In step one each of the workflow scores diagram could reach a maximum of 10 points (sum per workflow).

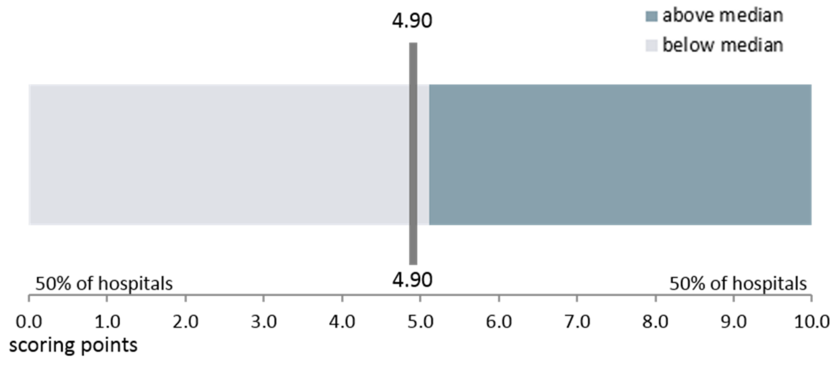

Figure 3. Simple score innovation view-example workflow score discharge-public hospitals (n=150)

To display the individual composition of a workflow score it was broken down to its workflow descriptor scores and displayed accordingly in a second step. Thus, there was a view for each of the descriptors data and information, functions, integration and distribution per workflow score. Here, the maximum value of scoring points was 2.5 points. Figure 7 shows an example of the specific combination of the workflow ward rounds with the workflow descriptor data and information. In other words, this score described how well ward rounds were supported by information technology with regard to the amount and appropriateness of the data and information provided for this workflow.

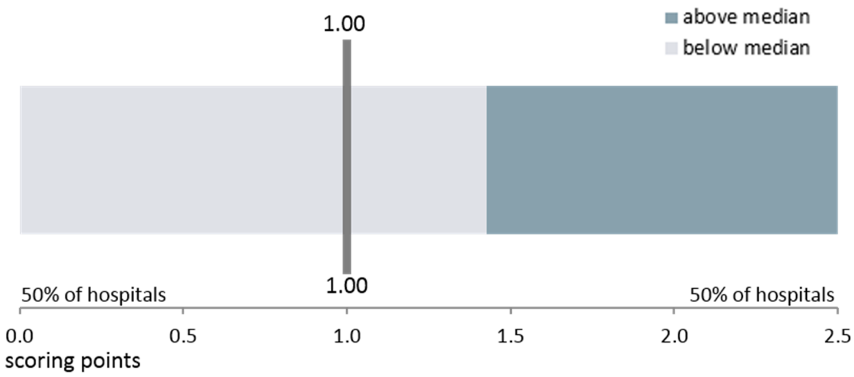

Figure 4. Simple score innovation view-example score combining the workflow ward rounds and the workflow descriptor data and information-public hospitals (n=150)

3.2.3 Score profiles at level 1 and 2

The meaning of all scores and score views was explained in so-called score profiles, which were attached to the views. They contained a definition, the purpose, the type, the aggregation level, related concepts, the codomain, the formula and the target group (see Table 4) [16].

Table 4. Indicator profile-workflow composite score (WCS)

Workflow composite score	
Definition and delimitation	The workflow composite score constitutes the highest level of all scores and measures the IT support of clinical processes per benchmark participant. It is composed of the sum of scores measuring the specific support for the processes ward rounds, pre-surgery process, post-surgery process and discharge.
Purpose	measurement of overall clinical information logistics in an organisation
Indicator type	composite score
Aggregation level	1
Related concepts	Diffusion of Innovations model by Rogers [23]
Codomain	0-40 points
Computation	sum of all workflow scores of level 2 or sum of all workflow descriptor scores of level 2
Target group	chief information officer, chief medical / nursing officer, chief executive officer

3.2.4 Level 3

The raw indicators used to build the WCS were depicted at level 3 in form of single indicator views and in form of multiple indicator views. Single indicator views represented - as the name reflects - one indicator and embraced the view types frequency view (see Figure 8), a view well-known in statistics, and performance bar (see Figure 9), which had been proposed by Few [43]. In both types of views, the category the individual hospital belonged to was marked: either in red as in case of the frequency views or in black as in case of the performance bars. Frequency views were employed for nominal data and ordinal data, performance bars only for ordinal data. Both types of single indicator views showed the distribution of values in the peer reference group.

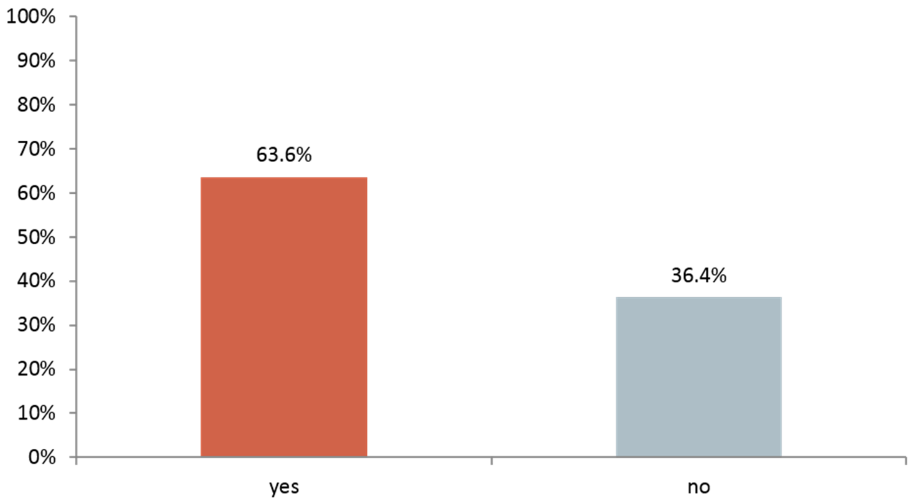

Figure 5. Single indicator view-frequency view-example integration of a workflow management system in the health information system–public hospitals (n=162)

Multiple indicator views encompassed the view types multiple distance view, multiple innovation view and multiple performance bar. The multiple indicator views reflected groups of raw indicators, *e.g.* measuring the degree of adoption of different types of clinical documentation. Multiple performance bars resembled single indicator performance bars [43] except that the bars of several indicators were depicted one below the other. Again, the individual value was presented within the distribution of values from all members of the peer reference group. In contrast, multiple distance views showed the distance between the individual value and the best of the peer reference group (see Figure 10) for the group of similar raw indicators. Technically speaking, multiple distance views were net diagrams, which are well established in statistics.

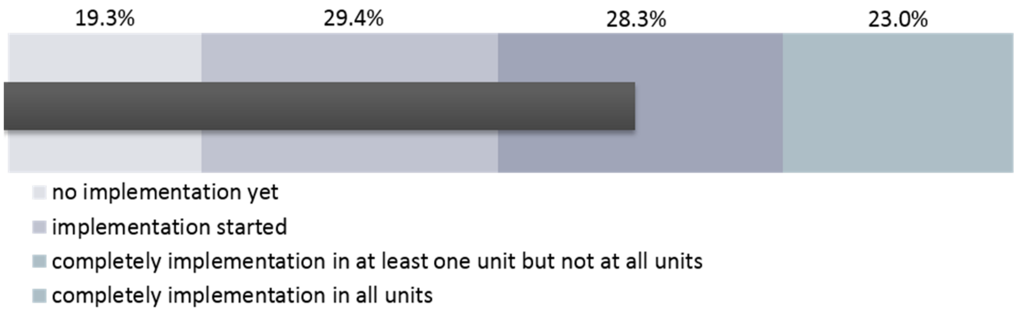

Figure 6. Single indicator view-performance bar-example degree of WiFi implementation-public hospitals (n=187)

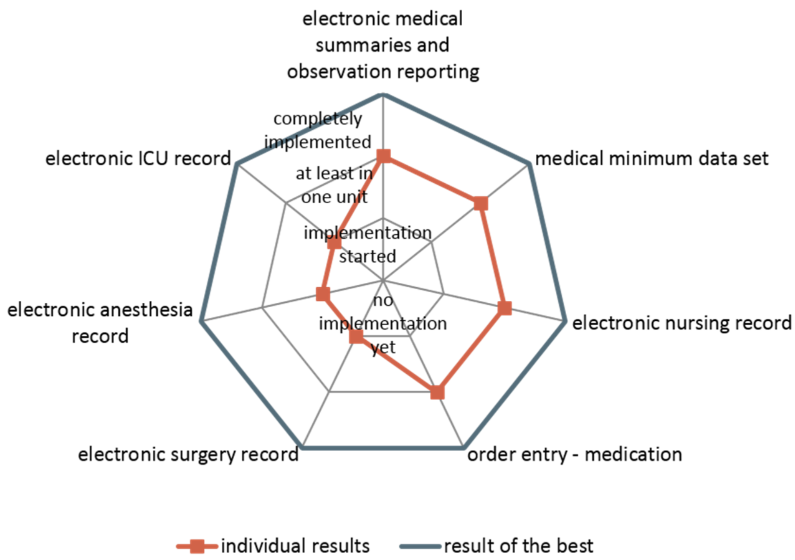

Figure 7. Multiple indicator view-multiple distance view-example existence of computerised systems for clinical documentation-public hospitals

The multiple innovation view, finally, expressed the implementation status of a group of raw indicators of the individual organisation (x-axis) in comparison to the frequency of this implementation status within the entire representative sample of hospitals the (y-axis). The resulting two-dimensional diagram was then divided into quadrants separating the entire field into a 2 × 2 matrix (see Figure 11). The two quadrants above the 50% line of the y-axis, *i.e.* the median, were called majority with the distinction of an early and a late majority. Organisations were called an early majority with regard to this IT function when they had implemented it in at least one unit (but not in all) or in all units. Organisations of the late majority had not implemented the IT function or were those in which the implementation started. If less than 50% of the hospitals showed this particular implementation status of the individual organisation, the organisation could be either an innovator or a laggard. Innovators had implemented the IT function (in at least one unit (but not in all) or in all units), laggards had not implemented it or the implementation (had just) started. The dot represented the category of the organisation and the frequency of this category (not the other potential categories) within the reference group. The multiple indicator views were implemented as proposed by [28] (In this view, the understanding of innovators, early majority, late majority and laggards deviated from the Rogers definition [23] who classified adoption units according to the percentage of availability not the implementation status.).

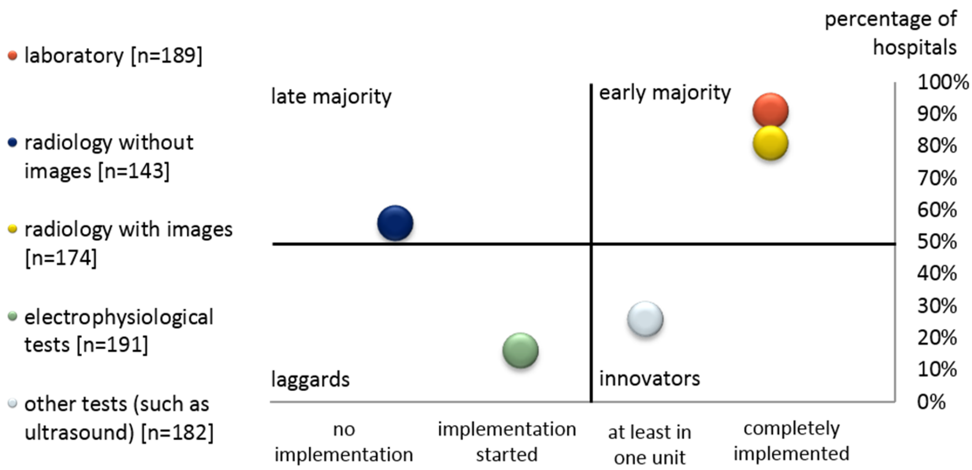

Figure 8. Multiple indicator view-multiple innovation view-example existence of computerised systems for order entry system for various tests-public hospitals

3.2.5 Toolbox of views

The views explained above in combination with tables constitute a toolbox of views that could be employed for the benchmarks of different types. Table 5 summarises these views in light of what they intended to measure, what benchmark type they supported and for which level they were most appropriate. Not all potential types of views were implemented at all levels. The ones actually used were selected followed the strategy:

- the benchmark should be the peer reference group in general
- the views should be most elaborate at level 3

Table 5. Toolbox of views (views in italics were implemented in the benchmark)

Measurement	Degree of innovation	Adoption rate	Status
Benchmark	**Peer reference group**	**Peer reference group**	**Best within peer reference group**
Level 1	*composite score innovation view*	table	table
Level 2	*simple score innovation view*	table	table
Level 3	*multiple innovation view*	*multiple performance bar, performance bar, frequency view*	*multiple distance view*

3.3 Publication of the benchmarks

The results of the benchmark were published stepwise and semi-automated using Microsoft Excel. A minimal version of the benchmark showing the results of three raw indicators of their choice were issued within one month after the end of the survey. In a second step, a short version with 16 tables and diagrams (*e.g.* WCS and its composition, workflow scores and their composition, clinical documentation functions, architecture of the information system) were produced, printed and sent as a paper brochure of 12 pages to the participants three months after the end of the survey. We chose a high quality paper version to provide a real (as opposed to a virtual) medium to the benchmark participants, which they could immediately show to their colleagues and the board members. Finally, they received the full report of 106 pages with 169 tables and diagrams as a pdf document three and a half months after closing the survey by eMail. In addition to the paper and pdf version, a fully dynamic dashboard was developed in Microsoft Excel (see Figure 12) and tested internally. This version was not meant to be used by the participants because identification data of the other benchmark participants were included. The dashboard consisted of a navigation area that reflected the three-dimensional multi-level model and a display area to present the different views. Whenever different types of views were available at one level the user could choose in a drop-down menu. The dashboard prototype demonstrated the feasibility of the approach but also its limitations. The computation and display of the views in Microsoft Excel took about 5 to 10 minutes per view or had other performance problems due to the large dataset.

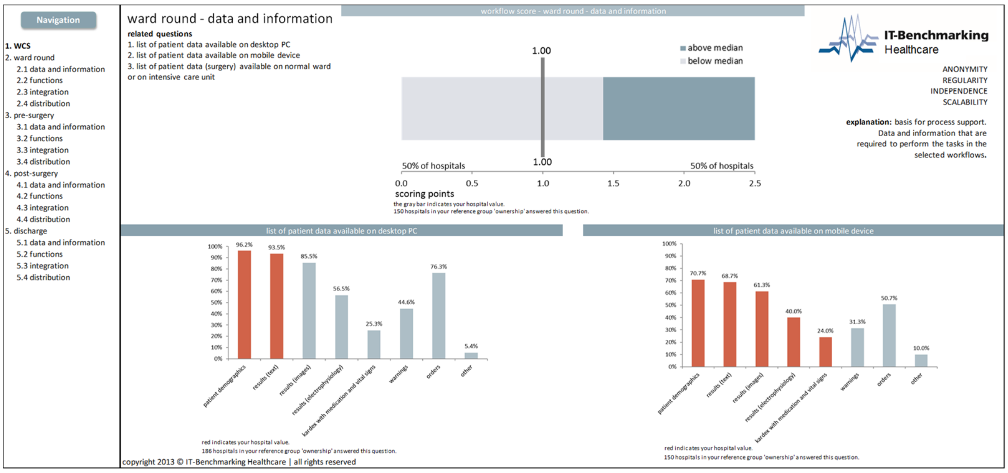

Figure 9. Screenshot of the dashboard-example workflow ward round-workflow descriptor score data and information

3.4 Evaluation

The evaluation questionnaire was returned by 67 out of the 199 benchmark participants, which corresponded with a response rate of 34%. The analysis showed that more than two third of the participants rated all scores as very comprehensible or comprehensible. However, there were differences with regard to the preference of the views in terms of their comprehensibility. While detailed and very well-known views, *i.e.* performance bars, frequency views, and tabular indicator profiles received positive ratings from more than 90% of the participants, combined and rather new views (the composite score innovation view, multiple distance view and multiple innovation view) were rated positively by only about 68% to 82% of the participants (see Table 6).

Table 6. Comprehensibility of the different types of views

Views	Very comprehensible	Comprehensible	Less comprehensible	Not comprehensible
Composite score innovation view (n=67)	23.9%	58.2%	14.9%	3.0%
Performance bars (n=66)[1]	37.9%	53.0%	7.6%	1.5%
Frequency views (n=65)	35.4%	58.5%	4.6%	1.5%
Multiple distance views (n=67)	22.4%	55.2%	16.4%	6.0%
Multiple innovation views (n=66)	22.7%	45.5%	28.8%	3.0%
Tabular indicator profiles (n=63)	27.0%	65.1%	6.3%	1.6%

Note. [1]Including multiple indicator view performance bars.

The Spearman rank correlation coefficient between the comprehensibility of the composite score innovation view and the utility of the workflow composite score was 0.59 (n = 64). This underlines the comprehensibility and utility of the workflow composite score.

4 Discussion

Performing IT benchmarks and presenting their results in an appropriate manner gains importance against the background of the increasing relevance of information management in organisations [46], the involvement of the chief information officers into the decision making processes at board level and their role as link between the board and IT operations [46, 47].

A good balance between highly aggregated facts and details that illustrate these compact facts seems desirable. The hierarchical system of the WCS to measure the performance of the organisation in terms of its clinical information logistics capacity [18] aims at providing this information balance. This study translated the WCS system into a three-dimensional multi-level model to visualise the benchmarking results at all levels. To this end, a set of views was developed (level 1 and 2) or taken from previous publications (level 3 and score profiles) and arranged to allow the comparisons with the peer reference groups of hospitals and the best of the groups. These views also enabled the benchmark participants to find out how the own organisation was classified into segments of innovation. The three-dimensional multi-level model seemed to be appropriate to present any highly aggregated lead indicator, here the WCS, and decompose it into its constituents. This approach could serve as a general principle of structuring benchmarks and guiding the benchmark participants through a jungle of data.

The benchmark results were made available to the participants in various paper and digital formats. A spreadsheet version proved to be less performing and difficult to ensure anonymity of the data. However, it leads the way towards a fully dynamic manner to present the results. Web-based solutions, where the data can reside safely in one place and where the user can interact with the benchmarking system in a self-determined way, seem most promising. This requires the technical basis of the benchmarks to be changed.

Apart from technical issues, which are important but were not the focus of this study, the visualisation system proposed and evaluated here provided encouraging results in terms of acceptance. The large majority of the users rated the various views as at least comprehensible. This applied to newly developed views and to conventional views. A preponderance of ease of comprehension towards traditional views is understandable and leads to the conclusion that these presentation formats definitely have a place in the canon of views. They must not be sacrificed to other more experimental versions. New versions, however, need to be explored. We found a group of views that were regarded as positive but may need some additional support to be accepted as comprehensible by nearly all participants. Mere explanations do not seem to be sufficient as these views came along with indicator profiles, which exactly provide these explanations. Further investigations on the role of innovation benchmarking are necessary [22] because both views that targeted innovation came off least positive in comparison to the other views. Very often, benchmarking aims at identifying cost and quality indicators [16, 48, 49], innovation has been focussed only rarely [19, 21, 50]. CIOs and the (other) board members need to be convinced that implementing IT innovation can entail competitive advantage in terms of better patient care and lower costs in the long run. Therefore, innovation benchmarks are a valuable instrument to govern the implementation of IT innovation in particular against the background of the strategic plan of the organisation. This is interesting in the view of the involvement of the CIO in strategic decision-making [46, 47].

It is interesting that multiple distance views also received positive rates from only about 75% of the participants despite the fact that net diagrams are well established. In this case, the term multiple distance view might have been misleading and some participants may not have recognised what this term denoted.

The main limitation is, in fact, the small sample of participants who evaluated the benchmark and its visualisation. Thus, the conclusions that can be drawn from these results are limited and conducting further benchmarks and presenting the results according to the three-dimensional multi-level model seems unavoidable. Simply presenting the different views to a group of experts is not advisable because a valid evaluation requires a valid context in which the evaluation takes place, *i.e.* a real benchmark with real chief information officers, who are interested in their benchmark outcome.

5 Conclusion

With the increasing importance of measuring IT adoption and utilisation [51-53] IT benchmarks will gain more and more importance. The practical procedures for conducting these benchmarks will have to undergo severe changes. In order to benchmark health organisations on a regular basis, the *time to display* needs to be shortened and this can only work with as much automation as possible. This study investigated important building blocks along this way, *i.e.* a visualisation system and appropriate views. It provided a solid mechanism for displaying the workflow composite score, a reliable and valid indicator of IT process quality.

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Competing interests

Parts of this work were presented at the eHealth 2014 Conference in Vienna on 22 May 2014 and published in the conference proceedings.

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Beitrag 7: Understanding Latent Structures of Clinical Information Logistics: A bottom-up Approach for Model Building and Validating the Workflow Composite Score

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Tabelle 8. Überblick Beitrag 7

Understanding Latent Structures of Clinical Information Logistics: A Bottom-up Approach for Model Building and Validating the Workflow Composite Score

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Abstract

<u>Background and Purpose:</u> Clinical information logistics is a construct that aims to describe and explain various phenomena of information provision to drive clinical processes. It can be measured by the workflow composite score, an aggregated indicator of the degree of IT support in clinical processes. This study primarily aimed to investigate the yet unknown empirical patterns constituting this construct. The second goal was to derive a data-driven weighting scheme for the constituents of the workflow composite score and to contrast this scheme with a literature based, top-down procedure. This approach should finally test the validity and robustness of the workflow composite score.

<u>Methods:</u> Based on secondary data from 183 German hospitals, a tiered factor analytic approach (confirmatory and subsequent exploratory factor analysis) was pursued. A weighting scheme, which was based on factor loadings obtained in the analyses, was put into practice.

<u>Results:</u> We were able to identify five statistically significant factors of clinical information logistics that accounted for 63% of the overall variance. These factors were "flow of data and information", "mobility", "clinical decision support and patient safety", "electronic patient record" and "integration and distribution". The system of weights derived from the factor loadings resulted in values for the workflow composite score that differed only slightly from the score values that had been previously published based on a top-down approach.

<u>Conclusion:</u> Our findings give insight into the internal composition of clinical information logistics both in terms of factors and weights. They also allowed us to propose a coherent model of clinical information logistics from a technical perspective that joins empirical findings with theoretical knowledge. Despite the new scheme of weights applied to the calculation of the workflow composite score, the score behaved robustly, which is yet another hint of its validity and therefore its usefulness.

Keywords: *clinical information logistics, clinical workflows, composite score, model building, health information technology, factor analysis*

1. Background and Significance

Providing accurate information, at the right time, in the right format and to the right actor is commonly described as the key aim and general definition of information logistics – an increasingly utilised construct among different research domains and industries [1,2]. Research on information logistics is strongly fragmented across various disciplines, as it is applied to multiple contexts for varying motivations. For example, it is being used to explain the local distribution of information, such as newspaper or radio, to increase productivity in information producing organisations (e.g. banks or insurances), or to increase efficiency in industrial production networks, such as the automotive industry [3]. Investigations within clinical contexts ("clinical information logistics") found potential application in process improvements – a crucial success factor of efficient IT support of clinical workflows [4,5]. Despite its use in multiple contexts and initiatives [2,4,6,7], information logistics is a rather young and poorly developed research domain, thus requiring more empirically founded investigations [3]. Research within clinical contexts [6,8] was often highly narrative and descriptive, pointing out basic aspects, benefits, and applications of clinical information logistics, yet rarely established an empirical methodology. Although process orientation, functions, data, integration, mobility and decision support were mentioned as key aspects [2,6], a comprehensive model is absent. Haftor and colleagues, therefore, concluded that the lack of a comprehensive approach and sound methodology leads to unjustified results [3]. Thus, underlying structures of "good" information logistics in the context of clinical processes are largely unknown while its increasing significance has been emphasised [9].

First attempts to address this gap were made by Liebe and colleagues [5] who followed a theory driven top-down approach based on relevant literature and expert discussions. This led to a framework, in which the construct "clinical information logistics" was subdivided into four basic components, referred to as descriptors:

1) "Data and information" as the basic requirement to perform tasks in the respective workflow (e.g. patient demographics, results (text, images & electrophysiology), medication, vital signs etc.).
2) "Functions" and IT applications that provide, process and store data for further use (e.g. clinical decision support systems (CDSS), computerised physician order entry (CPOE), electronic nursing record etc.).
3) "Integration" to allow interoperability between these functions and IT applications (e.g. hospital information system integration architecture, way of transferring patient data between systems etc.).
4) "Distribution" to describe the ability of disseminating data, information and functions to different points of care within or outside the own institution (access to data, available devices for use, mobility of data and applications, Wi-Fi-coverage, etc.).

The resulting framework was put into practice within a procedure for evaluating and benchmarking IT support of clinical workflows in German hospitals [10]. The workflows selected were required to be part of the core processes of hospitals and had to be sufficiently complex, including multiple professions, departments and institutions to ensure that they were qualified to represent the comprehensive scope of clinical information logistics [11]. Following these criteria, the four workflows "ward round", "pre-surgery care process", "post-surgery care process" and "discharge" were identified as most suitable [5].

Combining these four workflows with the four descriptors led to a 16-cell matrix, from which the relevant IT features were derived and corresponding items, i.e. questions, for the IT Report Healthcare survey 2013 [12] were developed. This linkage allowed the construction of a three-level hierarchy of key performance indicators (Figure 1). Level 3 contained detailed features (level 3.2) and more general items (level 3.1) from the survey. They were then aggregated in the descriptors for each of the processes (level 2) and ultimately merged in the so called workflow composite score (WCS, level 1), an overall measure of clinical IT workflow support on the theoretical foundations of information logistics. The WCS was proposed as a globally applicable instrument due to its foundation on the international literature and its validation with EHR concepts used worldwide [5].

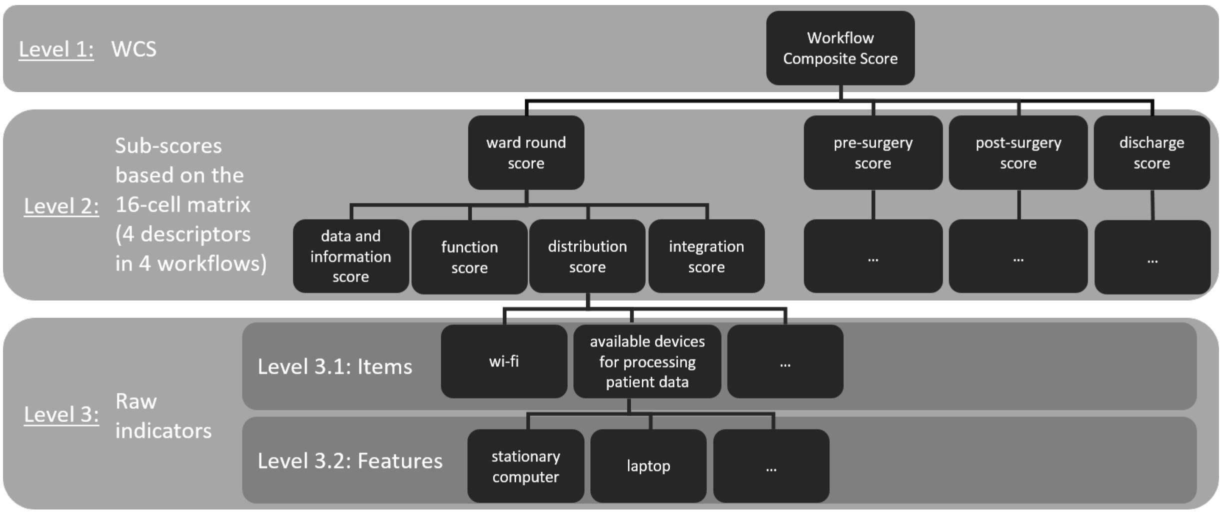

Figure 1: WCS levels of hierarchy

Unpacking clinical information logistics into the four descriptors presented above was realised by a theoretically driven top-down approach [5]. Largely following the literature (e.g. Jha and colleagues [13]), the conceptualisation of clinical information logistics was independent of the underlying empirical data. Even though this approach led to a comprehensive classification scheme that ultimately produced valid and predominantly reliable results, retrospective and data driven bottom-up attempts to further investigate and validate the measurement of clinical information logistics were still required [5]. In detail, there is a need for empirically testing the convergent and discriminant construct validity of clinical information logistics. This need is also stressed in the OECD "Handbook on Constructing Composite Indicators" [14], where applying multivariate analysis techniques is described as an integral part when developing composite scores in order to assess and evaluate the underlying data structure. Resulting insights from these analyses can then be synchronised with existing theoretical conceptions, strengthening the construct's theoretical understanding.

An important issue, hereby, is to empirically analyse underlying factors of clinical information logistics and evaluate to what extent these latent structures influence the construct. For this purpose, the descriptors pose a reasonable starting point since they already provide a systematic cluster. Having in mind that descriptors are rather to be seen as generic clusters to sort a comprehensive entity, it is justifiable to assume that they may have similar attributes to statistical factors, which in contrast aim to describe the inner texture of the construct. Furthermore, reliability testing of the descriptors revealed insufficient values for "integration" and "distribution" [5], which again encourages further investigation. Aside from this, the current items and features constituting the WCS are essentially equally weighted due to a lack of an alternative model. An empirically justified weighting procedure that accentuates important domains and suppresses the influence of negligible content is not only desirable for getting a better balanced score [14] but also helps to assess the robustness and sensitivity of the WCS against manipulations in its construction.

Similar studies demonstrate successful application of factor analytic approaches in conjunction with conceptualising and measurement of IT adoption [15–17], for building composite scores [18,19] as well as to test for construct validity of abstract phenomena [2,20]. However, to our knowledge there are no studies explicitly focussing on clinical information logistics.

The questions addressed in this study therefore are:

1) Might the descriptors categorise the illustrative elements of clinical information logistics that can also be observed as statistical factors?
2) If not, what other reliable factors underlie clinical information logistics instead that actually constitute good IT support of clinical workflows from a technical perspective?
3) How should an alternative, data driven weighting and aggregation procedure for the workflow composite score be realised?
4) How robust and reliable is the workflow composite score after modifying its construction in terms of factors and weighting?

By addressing these questions, the previously pursued top-down approach gets contrasted by a data-driven bottom-up methodology to eventually end up with another validation of the measurement of clinical IT workflow support with the help of the workflow composite score and an improved understanding of clinical information logistics.

2. Material and Method

2.1 Material

In order to maintain coherence in the validation procedure, this study was based on the same data set as used by Liebe and colleagues [5], i.e. data captured in the framework of the IT Report Healthcare 2013 [12]. The relevant part of the questionnaire was composed of 27 main questions (items) and 92 subjacent IT features. In total, 1317 chief information officers (CIO) representing 1675 German hospitals were surveyed in this report from which 259 responses were obtained (response rate 19,7%). To make sure all four workflows were equally represented in the data, we took a subsample of 183 hospitals that all possessed a surgery theatre and an intensive care unit.

2.2 Overview

To address the research questions, we chose a tiered factor analytic approach, comprising of a confirmatory factor analysis (CFA) and a subsequent exploratory factor analysis (EFA). Using this methodology, we were able to 1) empirically confirm or reject the descriptors as empirical factors using CFA, 2) reveal a possibly deviating factor structure using EFA and 3) derive an alternative weighting and aggregation procedure for the WCS from resulting factor loadings and eigenvalues[1] [21] that allowed further examination of its robustness.

Similar two-step CFA-EFA approaches proved to be useful [22] and were recommended for when there is a pre-existing theoretical idea about the construct to be studied [23]. In order to integrate these analyses into the WCS validation procedure, we embedded our work into the OECD guideline on constructing composite indicators [14]. Figure 2 displays how previous work on the WCS and our study fit into the nine steps described in this guideline.

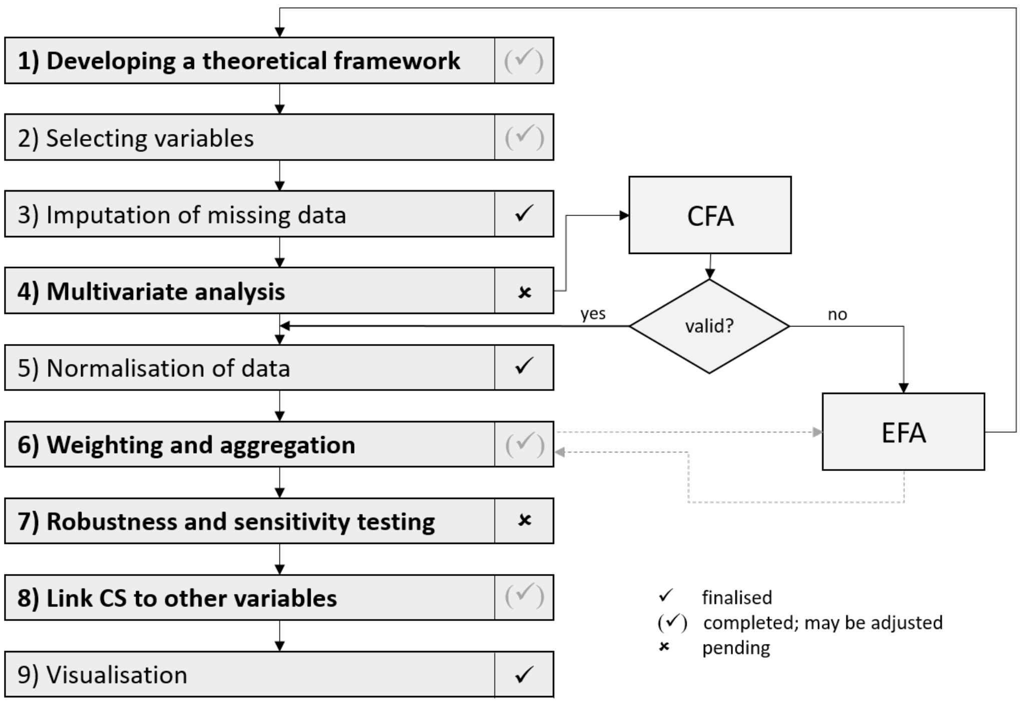

Figure 2: Study design embedded in the guideline on constructing composite indicators adapted from Nardo and colleagues [12]. Steps undertaken or re-done in this study are highlighted in bold.

The first three steps had previously been completed in the top-down approach [5] and the results obtained could be used unchanged in this study. Hence, we entered the process in step four, "multivariate analysis", to conduct the CFA. If the hypothesised factors turned out to be valid at this point, it would be possible to proceed straight with step five. If not, conducting EFA would be indicated. The results could be used for feedback and synchronisation with the theoretical framework, possibly leading to an adaption of variables used for the composite score (step 2). Following that, the EFA results could also be used in step 6, "weighting and aggregation". A specific procedure for this approach was described by the OECD [14] and was applied in several studies [18,21]. We adapted this procedure, particularly because other empirically based weighting techniques in the studies reviewed seemed arbitrary and were not backed by literature [16,24]. Sensitivity and robustness (step 7) were tested by comparing the newly weighted and aggregated

[1] A factor's eigenvalue reflects the variance in all the variables, which is accounted for by that factor, i.e. the sum of the squared factor loadings of a given factor. It can therefore be interpreted as the factor's explanatory strength.

WCS with the existing one. Furthermore, the alternative WCS version (WCS_{factor}) was correlated with external measures to assess its validity, based on Liebe and colleagues [5] (step 8).

A total of five models were build and analysed. Each workflow was analysed separately in order to reveal possible peculiarities. In addition, a workflow-spanning "overall" model was investigated which contained all variables used in the four workflow models, allowing a more generic interpretation of the results.

2.3 Admissibility criteria

The admissibility of performing factor analysis generally depends on the sample to variable ratio in the analysed dataset [25]. Despite strongly divergent recommendations [26], the dominant rule of thumb advises a ratio of 5:1 to 10:1 [27,28]. Since this criterion was not met applying factor analysis to features on level 3.2 (Table 1), analyses were carried out on item level 3.1, where ratios ranged between 6.8 and 8.7. To realise this approach, some IT features had to be aggregated as sum variables. For example, the binary features "patient demographics", "results (text)", "results (images)", "results (electrophysiology)", "kardex with medication and vital signs", "warnings" and "orders" on level 3.2 were aggregated to the sum variable "How many different types of data are available?".

Following strong recommendations of the methodological literature [23,29–31], we applied the underlying variable (UV) approach using tetrachoric and polychoric correlation coefficients[2] [32] in the correlation matrices since most of our variables were measured by a dichotomous or ordinal scale.

Table 1: Sample to variable ratios

Model	*n*	*Features*	*Items*	*Ratio*	
		Level 3.2	*Level 3.1*	*Level 3.2*	*Level 3.1*
Overall model	183	92	27	2.0	6.8
Ward round	183	76	24	2.4	7.6
Pre-surgery	183	53	21	3.5	8.7
Post-surgery	183	60	21	3.1	8.7
Discharge	183	59	24	3.1	7.6

2.4 CFA procedure

Polychoric and tetrachoric correlation coefficients were estimated using LISREL (version 9.1, SSI Inc.). These estimates were evaluated with a goodness-of-fit significance test integrated in LISREL. It assessed how many calculated coefficients deviated from the bivariate normal distribution of the underlying metric variables (on a 5% significance level) [33,34].

The model specification[3] was largely pre-defined by the allocation of IT features to the descriptors and workflows in previous works [5]. Correlations between the factors were estimated without restricting their height since we were interested in their actual interrelations. We additionally specified second-order models in all workflows because high correlations between the factors indicated that another variable, specified as "IT support" may underlie the factors [35].

Since applying the commonly used maximum likelihood estimation (MLE) is not advised when using polychoric correlation coefficients [29,36,37], we estimated the model parameters using unweighted

[2] Tetrachoric and polychoric correlation is a technique which assumes underlying continuous scales for each variable that is measured on a dichotomous or ordinal scale.

[3] "Model specification" refers to allocating variables to hypothesised factors and to determine possible interrelations between factors.

least squares (ULS) [38,39]. Moreover, the ULS method was shown to be robust in the face of violations against multivariate normal distribution [40,41].

The calculated models were evaluated according to six commonly used goodness-of-fit indices (Chi^2, Chi^2/df, Root Mean Square Error of Approximation (RMSEA), Adjusted Goodness-of-Fit Index (AGFI), Standardized Root Mean Square Residual (SRMR) and Comparative Fit Index (CFI) [23,41]. Subsequently, models were assessed by examining their parameters (i.e. factor loadings, error variances and correlations among factors).

2.5 EFA procedure

For conducting exploratory factor analyses, the previously calculated correlation matrices in LISREL were transferred to IBM SPSS (version 21). Although it was intended to include as many variables as possible, some collinear variables had to be removed in the exploratory analyses in order to calculate the EFA. The matrices' applicability was evaluated using the Kaiser-Meyer-Olkin (KMO) criterion with an acceptance range of ≥ 0.5 and following Bartlett's test of sphericity [42,43]. If the criteria were not met, variables with a low amount of variance accounted for by all factors, or variables with high factor loadings onto more than one factor were removed.

Since preconditions for choosing a parameter estimation method did not substantially differ to the CFA, ULS estimation was used for EFA as well. Oblique rotation was applied because we assumed factors to be interrelated and therefore correlated with each other. We extracted factors if their eigenvalue was greater than one and if the total variance explained by all factors was at least 50%. Additionally, the scree plot and content related considerations were used to determine the final number of factors in each model [44,45].

Factors were interpreted by consulting the pattern matrices (see supplementary material). A group of eight experts (all working and researching on IT support of clinical workflows) discussed the results and agreed on factor names and interpretation. Finally, the reliabilities of the extracted factors were empirically assessed using split-half reliability coefficients, corrected by the Spearman-Brown formula [46,47].

2.6 Weighting and aggregating the WCS

Factor loadings and eigenvalues calculated in the exploratory overall model allowed the development of an alternative version of the WCS (WCS_{factor}). Each factor was weighted (W_j) according to its sum of associated squared factor loadings (λ_{ij}), in relation to the sum of all squared factors loadings of the extracted factors, which reflects the relative contribution to the total variance explained (see equation 1 in which n stands for the number of factors and p for the number of factor loadings in the respective factor).

$$W_j = \frac{\sum_{i=1}^{p}(\lambda_{ij}^2)}{\sum_{j=1}^{n}(\sum_{i=1}^{p}(\lambda_{ij}^2))} \qquad \text{Equation 1}$$

In a similar manner, each item was weighted on the second level according to the portion of its variance explained by the respective factor in relation to the sum of variance explained by all variables (k) that were assigned to that factor (Equation 2).

$$w_{ij} = \frac{\lambda_{ij}^2}{\sum_{i=1}^{k}(\lambda_{ij}^2)} \qquad \text{Equation 2}$$

The relative weight of each item within the composite score could be obtained by multiplying both levels.

The resulting WCS_{factor} was compared with the original WCS in a paired t-test. Furthermore, WCS_{factor} results were contrasted in known-group comparisons regarding groups of different hospital size, ownership and teaching status. Finally, the WCS_{factor} was correlated with the same external validation measures as in the study by Liebe and colleagues [5].

3. Results

3.1 CFA

Whereas bivariate normality of the estimated underlying metric variables was violated in only 3-5% of all polychoric and tetrachoric correlation coefficients estimated throughout all models, the goodness-of-fit statistics indicated a substantial lack of fit in all specified confirmatory models (Table 2), including the second-order models. Furthermore, factor loadings were generally low while the factors themselves correlated strongly with each other, indicating that the hypothesised factors, i.e. the workflow descriptors, could not be distinguished empirically. The lack of fit clearly warranted further examination by exploratory factor analysis to find more appropriate factors.

Table 2: Goodness-of-fit statistics of the CFA with the respective acceptance range

Model	*df*	χ^2	$\chi^2/df \leq 2.5$	*p > 0.05*	*RMSEA ≤ 0.10*	*AGFI ≥ 0.9*	*SRMR ≤ 0.10*	*CFI ≥ 0.9*
Overall model	179	1163	6.5	p<0.001	0.139	0.892	0.101	0.676
Ward round	143	717	5.0	p<0.001	0.132	0.884	0.101	0.734
Pre-surgery	96	447	4.7	p<0.001	0.125	0.897	0.092	0.729
Post-surgery	96	436	4.5	p<0.001	0.125	0.894	0.093	0.736
Discharge	94	447	4.8	p<0.001	0.122	0.875	0.984	0.705

3.2 EFA

The sampling adequacy of the overall model following the Kaiser-Meyer-Olkin criterion proved to be "mediocre" with a value of 0.67 [48]. Additionally, Bartlett's test of sphericity was significant in all models with p<0.001. Conducting EFA was therefore permissible. Best possible representation of the 20 variables analysed was reached in a 5-factor solution explaining 63% of the total variance in the data (Table 3).

Table 3: Variance explained in the overall model

Factor	*Eigenvalues*		
	Total	*% of variance*	*Cumulative %*
1	6.252	31.259	31.259
2	2.255	11.274	42.534
3	1.720	8.602	51.136
4	1.307	6.536	57.672
5	1.144	5.720	63.392

Three items ("Which electronic data from the surgery are available on the intensive care unit?", "In which format are patient data transmitted to the normal ward and the intensive care unit?" and "Implementation status of electronic systems for medical guidelines and clinical pathways") had to be removed since linear dependencies (high correlations) with other similar variables in the dataset prevented the model from converging on the final mathematical solution. Additionally, another four items ("Is there a workflow management system integrated in your health information system?", "How many clinical units have an in-patient access to patient data?", "Are there electronic reminder functions for physicians and nurses concerning pending actions (e.g. orders) for patients before discharge?" and "Interface function: communication with external health care providers") were removed due to low communalities or strong cross loadings.

The factors were named based on primary variables and contextual deliberations as ”flow of data and information”, “decision support and patient safety”, “mobility”, “integration and distribution” and “electronic patient record (EPR)” (Table 4). Apart from “integration and distribution”, all factors were relatively stable with regard to the number of variables associated and the height of loadings. Correspondingly, the reliability of the factors was found to be good with coefficients ranging from 0.775 to 0.903 (Table 6). “Integration and distribution” however, was not reliable with a coefficient of 0.313. Correlations between factors were rather low and ranged between a maximum coefficient of -0.3 and +0.3.

Table 4: Factor loading matrix of the overall model. Loadings below 0.25 are left blank.

Overall model						
Item	*Factor*					*Interpretation*
	1	2	3	4	5	
Is the surgery date scheduled electronically in your institution?	.966			.321	.260	Flow of data and information
Which data is automatically provided in electronic form for the medical summary?	.721					
Which electronic data is accessible for the anaesthetist and surgeon before surgery?	.648					
Which electronic data from the surgery are available on the normal ward?	.565		-.269			
How are patient data transmitted to the normal ward?	.539					
Clinical decision support functions (e.g. clinical reminders, alerting, medication therapy)		.979				Decision support and patient safety
How many clinical units have access to an electronic system that supports medical guidelines or clinical pathways?		.682				
Patient safety functions (e.g. tracking of medication loop, critical incident reporting system, electronic identification of patients, medical supplies, drugs & specimen)	.252	.329				
Clinical documentation functions (e.g. medical, nursing, ICU, anaesthesia & surgery documentation)	.262	.288				
Which patient data are available on mobile devices?			-.733			Mobility
How many clinical units in your institution do have mobile access to the patient data?			-.691			
What is the degree of Wi-Fi implementation in your institution?			-.689			
Which electronic devices do clinicians use for processing patient data?			-.300			
Is the medical summary made available electronically to the general practitioners?				.833		Integration and distribution
How would you describe the architecture of your health information system?				.545		
Please describe the availability of the electronic patient record system in your institution.					-.638	Electronic patient record
Which patient data are available on PC workstations for ward rounds?	.271		-.396		-.487	
Interface functions (e.g. inpatient management (ADT), outpatient management, communication with external providers)				.325	-.426	
Supply chain functions (e.g. meal ordering, pharmacy, materials management)					-.380	
Order entry and observation reporting (e.g. radiology and nuclear medicine, electrophysiology, lab values)					-.259	

Although the number of factors somewhat varied among the different workflow models (see supplementary material), the measures of sampling adequacy (KMO criterion) and the general factor structures were found to be quite similar (Table 5). Particularly the factors describing the flow of data and information, decision support systems and mobility were reflected in all models. Yet a few differences were encountered when focusing on ward rounds since a factor called "process control" was extracted. However, it showed low split-half reliability (Spearman-Brown coefficient of 0.443) and only had two items associated with it.

Table 5: Overview of workflow specific factor structures

Ward round		***Pre-surgery***		***Post-surgery***		***Discharge***	
Factor	*Number of Items*	*Factor*	*Number of Items*	*Factor*	*Number of Items*	*Factor*	*Number of Items*
Flow of data and information	3	Process control & general functions	7	Flow of data and information	3	Flow of data and information	3
Decision support	2	Decision support	2	Decision support	3	Decision support and patient safety	5
Mobility	5	Mobility	3	Mobility	2	Mobility	5
Process control	2			Electronic patient record	6	Integration and distribution	2
General patient centred functions and data	5					Electronic patient record	3
	17		12		14		18

Except for the factors "integration and distribution" and "process control", all extracted factors were found to be reliable with Spearman-Brown coefficients ranging from about 0.6 to 0.9.

Table 6: Split-half reliabilities

Factor	*Number of features*	*Number of features half A*	*Number of features half B*	*Spearman-Brown coefficient*
Overall model				
Flow of data and information	22	11	11	0.903
Decision support and patient safety	19	10	9	0.794
Mobility	16	8	8	0.775
Integration and distribution	2	1	1	0.313
Electronic patient record	21	11	10	0.829
Ward round				
Flow of data and information	9	5	4	0.853
Decision support	5	3	2	0.891
Mobility	17	9	8	0.700
Process control	2	1	1	0.443
General patient centred functions and data	29	15	14	0.890
Pre-surgery				
Process control & general functions	33	17	16	0.883
Decision support	5	3	2	0.891
Mobility	9	5	4	0.604
Post-surgery				
Flow of data and information	9	5	4	0.772
Decision support	6	3	3	0.837
Mobility	2	1	1	0.625
Electronic patient record	26	13	13	0.851
Discharge				
Flow of data and information	14	7	7	0.844
Decision support and patient safety	6	3	3	0.752
Mobility	15	8	7	0.673
Integration and distribution	2	1	1	0.313
Electronic patient record	14	7	7	0.831

3.3 Comparing the WCS_{factor} with the $WCS_{original}$ and its validation

Table 7 shows the outcome of the alternative weighting and aggregation procedure described in section 2.6. It resulted in a slightly lower workflow composite score (WCS_{factor} = 22.89) compared to the original one ($WCS_{original}$ = 23.38). Although this difference of the means was significant ($p < 0.001$) following the t-test (Table 8), it was not meaningful given the fact that the WCS was designed to range between 0 and 40. The standard deviation, the range and the properties of the distribution barely changed at all (Table 7).

Table 7: Descriptive statistics of the two WCS versions

n = 183	$WCS_{original}$	WCS_{factor}
Mean	23.38	22.89
SD	5.57	5.55
Variance	31.04	30.82
Skewness	0.10	0.19
Kurtosis	-0.23	-0.19

Range	28.84	28.19

Table 8: Results of the paired t-test for differences of the means between $WCS_{original}$ and WCS_{factor}

n = 183	*Paired Differences*		*Standard Error Mean*	*95% CI*		*T*	*df*	*p (2-tailed)*
	Mean	*SD*		*Lower*	*Upper*			
	0.489	1.896	0.140	0.212	0.766	3.489	182	0.001

When contrasting the two versions of the WCS in known-group comparisons, no noteworthy differences in the changes across these groups could be found (Table 9). The same held true for external validation against the European Electronic-Medical-Record-Adoption-Model (EMRAM Stages) and the Electronic-Health Record-Adoption-Model by Jha and colleagues [13], which were previously approximated in our data by Liebe and colleagues [5] based on published model descriptions (Table 10). Correlations with these models ranged between 0.36 and 0.43 and did not differ depending on the WCS version.

Table 9: Group differences between the two versions of the WCS

Size (number of beds)	*Mean $WCS_{original}$*	*Mean WCS_{factor}*
up to 199 (n = 38)	19.77	19.86
200 to 399 (n = 60)	23.84	23.27
400 to 599 (n = 39)	23.49	22.60
600 to 799 (n = 16)	24.11	23.97
800 and more (n =30)	26.49	25.78

Ownership	*Mean $WCS_{original}$*	*Mean WCS_{factor}*
Public (n = 150)	23.61	22.32
Private (n =33)	22.33	21.37

Teaching status	*Mean $WCS_{original}$*	*Mean WCS_{factor}*
no teaching hospital (n = 55)	22.30	20.91
teaching hospital (n = 101)	23.61	22.46
university hospital (n = 13)	28.91	27.93

Table 10: Correlation with external validation measures

n = 183	$WCS_{original}$	WCS_{factor}
$WCS_{original}$	1	
WCS_{factor}	.942**	1
Jha	.364**	.395**
EMRAM	.419**	.413**

** The correlation is significant with α = 0.01 (2-tailed).

4. Discussion

4.1 Summary

This study aimed to reveal latent structures of clinical information logistics for the first time. Analyses were carried out with regard to the selected clinical core processes “ward rounds”, “pre-surgery”, “post-surgery”, and “discharge”. This allowed the validation of the workflow composite score (WCS) as the central measure of IT support, using a tiered approach with confirmatory and exploratory factor analyses. Model parameters calculated in the exploratory analysis were used for an alternative weighting and aggregation procedure to construct a new composite score based on the same variables that allowed the robustness of the original WCS to be assessed. Although the previously described workflow descriptors of clinical information logistics, which were developed in a top-down fashion, could not be confirmed as statistical factors, the factor structure gained from EFA showed clear conceptual similarities. The WCS turned out to be stable in spite of changes in its construction, which indicated its robustness.

4.2 Descriptors or factors?

Initial assumptions about the descriptors “data and information”, “functions and applications”, “integration” and “distribution” also serving as statistical factors had to be discarded in light of deficient measures of model fit and model parameters in the CFA.

However, this does not seem to be very surprising given the word “descriptor” already suggests that they are not based on empirical conditions but are rather extracted from the literature and primarily based on content-related deliberations [5]. Descriptors naturally follow the purpose of describing a phenomenon that they statically systematise without claiming to have factor-like properties [49]. Factors, in contrast, are less static and have the capacity of explaining the construct’s empirical structure [50].

Thus, descriptors and factors allow different perspectives on the same subject and therefore share common themes. As table 11 shows, factors rearrange the themes towards greater empirical precision, both in terms of increased specification and combination.

Table 11: Conceptual difference and connection between descriptors and factors

<table>
<tr><td></td><td></td><td colspan="4">workflow descriptors (top down)</td></tr>
<tr><td></td><td></td><td>data and information</td><td>functions</td><td>integration</td><td>distribution</td></tr>
<tr><td rowspan="6">workflow factors (bottom up)</td><td>flow of data and information</td><td>specification</td><td></td><td></td><td></td></tr>
<tr><td>Mobility</td><td></td><td></td><td></td><td>specification</td></tr>
<tr><td rowspan="2">electronic patient record</td><td>specification</td><td>specification</td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td>combination</td><td>combination</td></tr>
<tr><td>integration and distribution</td><td></td><td></td><td>combination</td><td>combination</td></tr>
<tr><td>decision support and patient safety</td><td></td><td>specification</td><td></td><td></td></tr>
</table>

While workflow descriptors simply speak of “data and information”, the workflow factors specify that it is the “flow of data and information”, not data and information in general, but those within the “electronic patient record”. The same applies to the workflow descriptor “functions”, where those are meant which are collected under the roof of the “electronic patient record” or those which are related to “decision support and patient safety”. In a similar manner, the workflow descriptor “distribution” was specified into distribution due to “mobility”. At the same time, general distribution (of data, information and functions) was combined with the other workflow descriptor “integration” to form the workflow factor “integration and distribution”, which shows that - technically speaking - both cannot be separated. The workflow factor “electronic health record” can also be interpreted as a combination of the two workflow descriptors “data and information” and “functions”.

4.3 Latent structures: the new approach to understanding clinical information logistics

The added value of factors is their strength to identify the coherent patterns of clinical information logistics that explain large portions of the variance in the dataset. In the following paragraph, the factors of the overall model will be described in greater detail and put into the context of current literature.

Variables loading on the first factor interpreted as "flow of data and information" (split-half reliability of 0.903) primarily reflected the availability of data in each process step. Nonetheless, the "electronic scheduling of the surgery date" as the primary variable in that factor tells that it is not only limited to patient data but rather includes different elements of process integration. The factor can be considered to be quite stable due to high factor loadings and the number of variables associated with it [27]. By exposing this factor, we were able to highlight the empirical manifestation of the a priori argued process orientated nature of clinical information logistics [2]. These findings correspond well with the current literature, as accurately fitted integration of clinical information technologies into workflows is a subject of increasing interest in research [51] and is considered to be a key aspect of clinical information logistics [6].

The second factor "decision support and patient safety" was primarily constituted by the variables "decision support systems" and "medical guidelines" but also slightly influenced the presence of patient safety systems in the overall model. This factor represents innovative elements of clinical information logistics in the sense that affiliated applications provide semantic analyses [6] for the focal point of all hospital workflows, i.e. the professional clinical decisions made regarding further patient treatment and care in general. We showed that this specificity of clinical decision support systems is also reflected by a statistical distinctiveness. Similar conclusions can be drawn from the principal component analysis carried out by Blavin and colleagues [15] and Everson and colleagues [17], that separated corresponding groups of variables (clinical guidelines, clinical reminders, alert functions and drug dosing support) empirically from other EPR functions. Moreover, Bucher and Dinter [2] found analytic elements of information logistics to be one of its key factors. Bright and colleagues [52] pointed out that CDSS have proven positive effects, particularly on patient treatment processes, which underpins the relevance of this factor.

In the descriptor model, "mobility" was considered as a mere sub-element of the descriptor "distribution". We could reveal that mobility is a distinct factor of its own that affects good workflow support. High factor loadings and marginal differences across the models calculated, together with a split-half reliability of 0.7, indicated a solid reliability and stability. Mobility is widely regarded to possess great potential and power for improving and shaping clinical core processes [53,54]. Relocating IT functions directly to the point of care allows workflows to become more flexible and thereby clearly addresses the "right location" as one of the key objectives of clinical information logistics.

A further factor extracted in the overall and discharge model was called "Integration and distribution", which was associated with only two variables: the type of the HIS architecture and the way of transmitting the discharge summary to the general practitioner (scaled with: not at all / via Email / via portal solution). It was therefore insufficiently represented with regard to requirements of stable factors [55]. Despite its deficient stability and reliability, "integration and distribution" is a fundamental requirement for effective usage of clinical information systems [56]. It is therefore desirable to capture more redundancies of this factor in future surveys.

The last factor in most models was summarised as "electronic patient record" that pooled general patient-centred functions and data. In spite of somewhat diffuse variables with lower factor loadings, it showed good reliability values (Table 6). The electronic patient record plays a central role when trying to electronically support clinical workflows. It can be understood as a vessel, merging required data and highly communicative functions, thus enabling various clinical tasks to be performed [57,58].

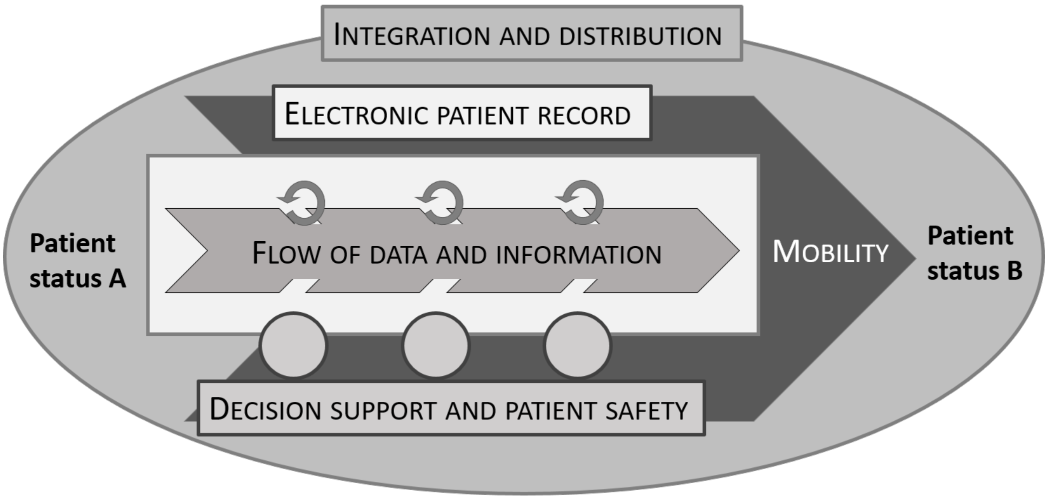

Figure 3: Conceptual model of clinical information logistics based on the structure of the factors

When setting a stronger focus on content-related considerations, the empirical patterns of clinical information logistics can be transferred and displayed in a conceptual model (Figure 3). The major purpose of clinical information logistics is to provide the best possible information support for the patient's treatment and thus the transition from patient status A to B [9]. This model illustrates that the process-orientated flow of data and information constitutes the backbone of this support. Data and information need to be passed along and made available in different stages of diagnostics and treatment, from admission to discharge. This flow of data and information should be organised in a flexible manner and should include various iterations. Along this process, there are several decision nodes (displayed as circles in Figure 3), e.g. "Should the patient receive surgery?", "What drugs should be taken?", that are ideally supported by clinical decision support systems and ultimately target the safety of the patient and the quality of care. The electronic patient record serves as the highly communicative frame that provides access to the corresponding data, information, and functions. Finally, technical integration and distribution are needed as an overarching requirement to allow communication between the IT functions implemented inside and outside of the organisation. Ideally, all data, information and functions are made available in a mobile manner to maximise flexibility and interaction with the system at the point of care.

4.4 Technical approach towards clinical information logistics

Measuring and evaluating IT workflow support incorporates different perspectives: technical, sociotechnical and management viewpoints [59–63]. The WCS previously described by Liebe and colleagues [5] and now re-assessed in this study covers the technical part of understanding this support, described as clinical information logistics. We propose that in the complex and multi-perspective arena of evaluating health IT systems, it is advantageous to first explore the technical potential of good IT workflow support in depth before incorporating models that focus on the interplay between technical, organisational, and human factors. A deep understanding of the technical components that reflect the structure and process quality of IT support is in our view a fundamental pre-requisite to assess the outcome of IT support from a user perspective. The presented results establish the foundation of further analysis and further composite scores that cover socio-technical factors as well as management and governance issues.

4.5 Validating the WCS

The applied method for weighting and aggregating variables corrects for overlapping information between correlated items and accentuates the construct's latent structures at the same time [14]. Empirical properties of clinical information logistics are therefore better reflected in the final measure. Yet, the major disadvantage of this approach is the dependency and sensitivity to modifications of the data base it is applied to [21]. Problems in factor analysis such as small sample size, erroneous parameter estimates and choice of extraction and rotation, influence the weights. On the other hand, it may be desirable to have a more flexible composite score that has the ability to adapt to different databases. Importantly, the technique has been proven to work in practical use and is supported by literature [14,18,21].

Despite some substantial differences in the weights between $WCS_{original}$ and WCS_{factor}, the effect on the final measure is negligible. The significant difference between the means can be ignored given its low extent and the mostly unchanged measures of dispersion and distribution. These findings corresponded with the unchanged distribution in different hospital groups and the invariable correlation coefficients with external criteria. This leads to the conclusion that the content (composition of variables) of a composite score of that size is more decisive than the aggregation and weighting system used. It furthermore demonstrates the robustness of the WCS and suggests that the original WCS already produced valid results.

4.6 Limitations

Linear dependencies (high correlations) and non-convergence posed a problem when trying to fit models and estimate factor structures. Consequently, we had to remove a few variables in most models that potentially threatened the integrity of the construct. However, we were able to mitigate this problem by calculating and fitting several different process models. Clear constants in the factor structure emerged from comparing these models which are well reflected in the overall model. Nonetheless, factors inherently depend on the dataset they were based upon which makes them potentially volatile over time. With regard to exploratory factor analysis, there are vast methodological options to choose from when determining the number of factors extracted, choosing the estimation algorithm, choosing a rotation method, and when interpreting factors [27]. Especially, the almost infinite mathematically identical solutions when rotating factors cannot be coped with without subjective assessment and evaluation of the meaningfulness and usefulness of the solutions. We tackled these disturbances inherent to the method by closely following methodological recommendations from the primary literature (e.g. [27,32,37]) in order to minimise arbitrary decisions. Yet, more comprehensive validation measures should be addressed in further research.

Since all analyses were performed on the item level rather than the more nuanced feature level, results are to be viewed as a fundamental dimensioning on a somehow abstract meta level. It can be assumed that those empirical structures could be refined when setting a stronger focus onto the feature level by, for example, applying repeated data reduction techniques. However, the principal component analysis by Everson and colleagues [17] and Blavin and colleagues [15] on datasets that contained variables very similar to many features in our data, suggest that most of our groupings are justifiable since they found very similar clusters in their component structure.

It would be meaningful to eventually enrich our model by incorporating the user perspective, such was the case in the study of Otieno and colleagues [19]. In contrast to Otieno's proposed procedure to measure and benchmark the effectiveness of electronic medical record systems, the strength of the WCS-based IT benchmarking is not only its emphasis on process orientation, but also the significantly larger sample size. Still, extending the framework to integrate aspects of system quality (e.g. perceived availability, usage and user satisfaction) will require incorporating the clinician's perspective. This will allow a comprehensive evaluation in terms of technical, managerial, and psycho-social aspects of the hospital environment with regard to IT [61], for which this model presents the essential (technical) basis. Choosing the CIO's perspective on this occasion is warranted since the CIOs are not only best suited for assessing the technical potential of an IT system in a hospital [64] but are also primarily responsible for providing the solutions needed and for controlling efforts to enhance the IT support.

5. Conclusion

The analyses led to an improved understanding about what latent structures underlie and determine clinical information logistics from a technical perspective. The five main factors found (flow of data and information, clinical decision support and patient safety, mobility, integration & distribution and electronic patient record) allowed us to build a theoretical model of clinical information logistics. In order to assess the validity of the workflow composite score, we contrasted the previously applied top-down approach with a data driven bottom-up methodology that was embedded into the OECD's recommendations for constructing a composite index. It could be shown that workflow descriptors and workflow factors are similar in a way, but only the workflow factors provide insight into the structure of clinical information logistics as a construct. Despite deviating theoretical dimensions, we were able to demonstrate the robustness of the WCS when applying a completely rebuilt weighting and aggregation procedure. This again confirms its overall consistency. We therefore encourage broader usage of the workflow composite score and clinical information logistics as a theoretical framework in research and benchmark initiatives.

Author's contributions

ME and UH were responsible for the conception and design with substantial contributions from JL. Data analysis and interpretation was conducted by ME with contributions of all co-authors, especially with regard to data interpretation. ME and UH wrote the manuscript. JL, JT and JH revised it critically before submission.

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Conflicts of interest

None.

Summary points

What was already known before

- Clinical information logistics poses a useful theoretical framework for researching and measuring IT support of clinical processes. However, little was known about the empirical patterns of entities constituting clinical information logistics.
- The workflow composite score (WCS) is a suitable indicator to measure the degree of IT support of clinical processes on several levels. Yet, a data driven validation procedure of its robustness was still required.

What the study added to our knowledge

- Underlying factors of clinical information logistics are “flow of data and information”, “mobility”, “clinical decision support and patient safety”, “electronic patient record” and “integration and distribution”. These factors explain great portions of the variance of the construct and allowed a coherent model of clinical information logistics to be built that supports its process orientated nature and reveals general determinants of good IT workflow support from a technical perspective.
- Despite a new scheme of weights applied to the calculation of the workflow composite score, the score behaved robustly, which is yet another hint of its validity and therefore its usefulness. The composition of variables constituting a composite indicator of this size seems to be of greater relevance than the weights applied to those variables.

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Beitrag 8: Exploring Innovation Capabilities of Hospital CIOs: An Empirical Assessment

Titel	Exploring Innovation Capabilities of Hospital CIOs: An Empirical Assessment
Autoren	Moritz Esdar Jan-David Liebe Jan-Patrick Weiß Ursula Hübner
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Link	http://ebooks.iospress.nl/volumearticle/46367
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Tabelle 9. Überblick Beitrag 8

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

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

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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.

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.

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 $\alpha = .71$. Similarly, component 1 showed good internal consistency ($\alpha = .78$) whereas components 2 ($\alpha = .64$) and 3 ($\alpha = .52$) 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. 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.

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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Beitrag 9: Innovative Power of Health Care Organisations Affects IT Adoption: A bi-National Health IT Benchmark Comparing Austria and Germany

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Tabelle 10. Überblick Beitrag 9

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

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Keywords*:* IT adoption, IT benchmarking, health IT, eHealth, Austria, Germany

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 than in Germany, two countries with nearly identical healthcare systems. We therefore aimed at investigating whether these differences still persisted and if this was the case whether they would be associated with hospital intrinsic factors, i.e. the innovative power of the organisation and hospital demographics. We measured the "perceived IT availability" and "innovative power" of the organisation in 464 German and 70 Austrian hospitals by a questionnaire with 52 items given to the directors of nursing in 2013/2014. Our findings confirmed a significantly greater IT availability in Austria than in Germany with regard to the aggregated composite score "IT function" and to the individual IT 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). In Germany, only "identification of samples" (OR=0.39) was significantly more often available. "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 likely in Austria than in Germany. The hospital demographics "size" and "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 legislation. Due to indicators that hint at a more favourable financial situation in Austrian hospitals we argue that they could possess a larger degree of freedom to feel innovative and act accordingly. We conclude, that 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 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.

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 met 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 (Tab. 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, and a shorter average length of stay.

Indicator	**AT**	**DE**
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

Table 1 Selected indicators describing the healthcare systems in Austria and Germany. 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 Glance statistics [20].

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 (Fig. 1). The benchmark object in our study was the availability of IT functions and systems in the health or hospital information systems. The availability was judged by the clinical stakeholders as the experts, who are familiar with the functions and 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.

In our framework, we assume that the adoption behaviour 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 and systems?
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?

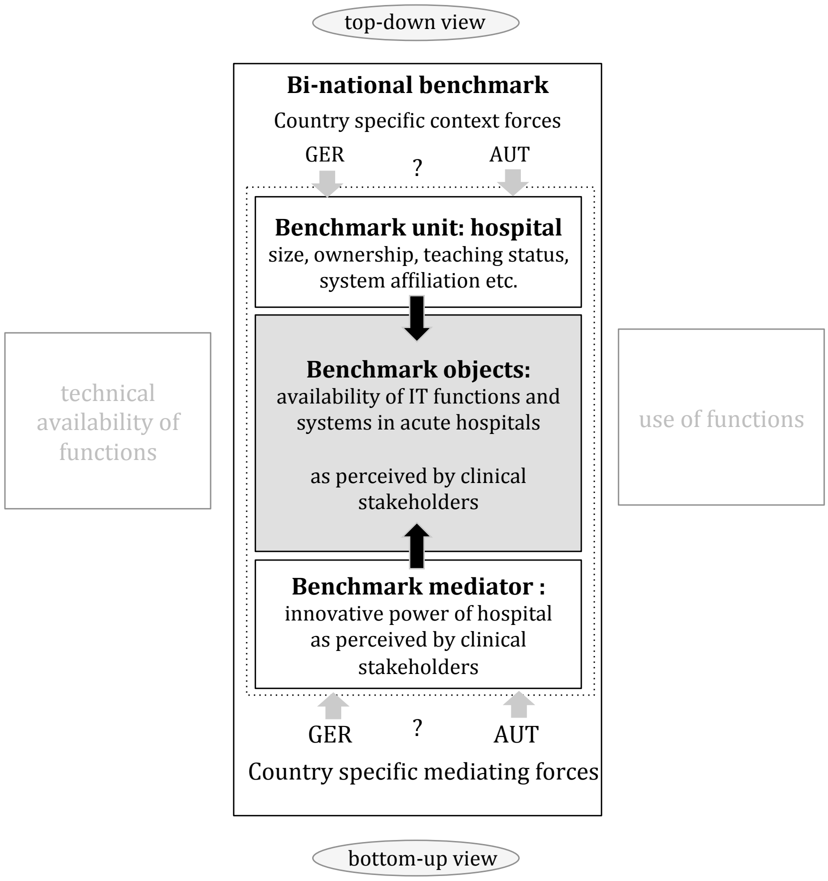

Figure 1: Research Framework of the eHealth Benchmark between Germany and Austria

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

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. 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[1] is shown in the Appendix A.

Data management and statistical analysis

1,754 eMail addresses of German and 169 of Austrian directors of nursing in hospitals could be identified by Internet research. They represented 90.9% percent of the German and 95.5% of the Austrian acute hospitals. The questionnaire was made available to the them between November 2013 and February 2014 [23] utilising the online survey tool Unipark.

All results were analysed with 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 B).

In order to compare both countries, we used the Workflow Composite Score (WCS) [26], an aggregated score which measures the hospital’s IT potential to support clinical workflows using four *descriptors* represented by the sub-scores: (1) data and information, (2) IT function, (3) integration and (4) distribution. To evaluate the IT adoption of both countries we utilised the sub-score "IT functions" (expressed as values from 0 to 100 points). It is a highly reliable score (split half reliability r=0.89) that integrates the 27 IT functions addressed in this survey. The sub-score served as criterion in a stepwise forward multiple linear regression analysis, into which the 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 (stage 1) and for demographic variables and “innovative power” (stage 2). Stage 2 adjustment was performed to investigate a potentially selective effect of “innovative power” on certain IT functions

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. There were no country specific statistical differences with regard to “size”, “system affiliation”, “teaching status” and availability of “surgery” (Tab. 2). Only ownership became

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

significant with an odds ratio of 2.24 (95% CI 1.31-3.78), i.e. a 2.24 greater chance to have a for profit hospital in Austria than in Germany (Tab. 2).

Table 2 Results of univariate logistics regression analyses for hospital demographics (predictor) and country (criterion) of the sample (n=534).

Sample	Overall	Germany	Austria	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 1 shows the frequency distribution of the adoption[2] in the two countries for the 27 IT functions. 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" (Δ= 35.8 percentage points) whereas on the other end the function "identification of samples" showed the highest difference in favour of Germany (Δ= 23.0 percentage points).

[2] 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.

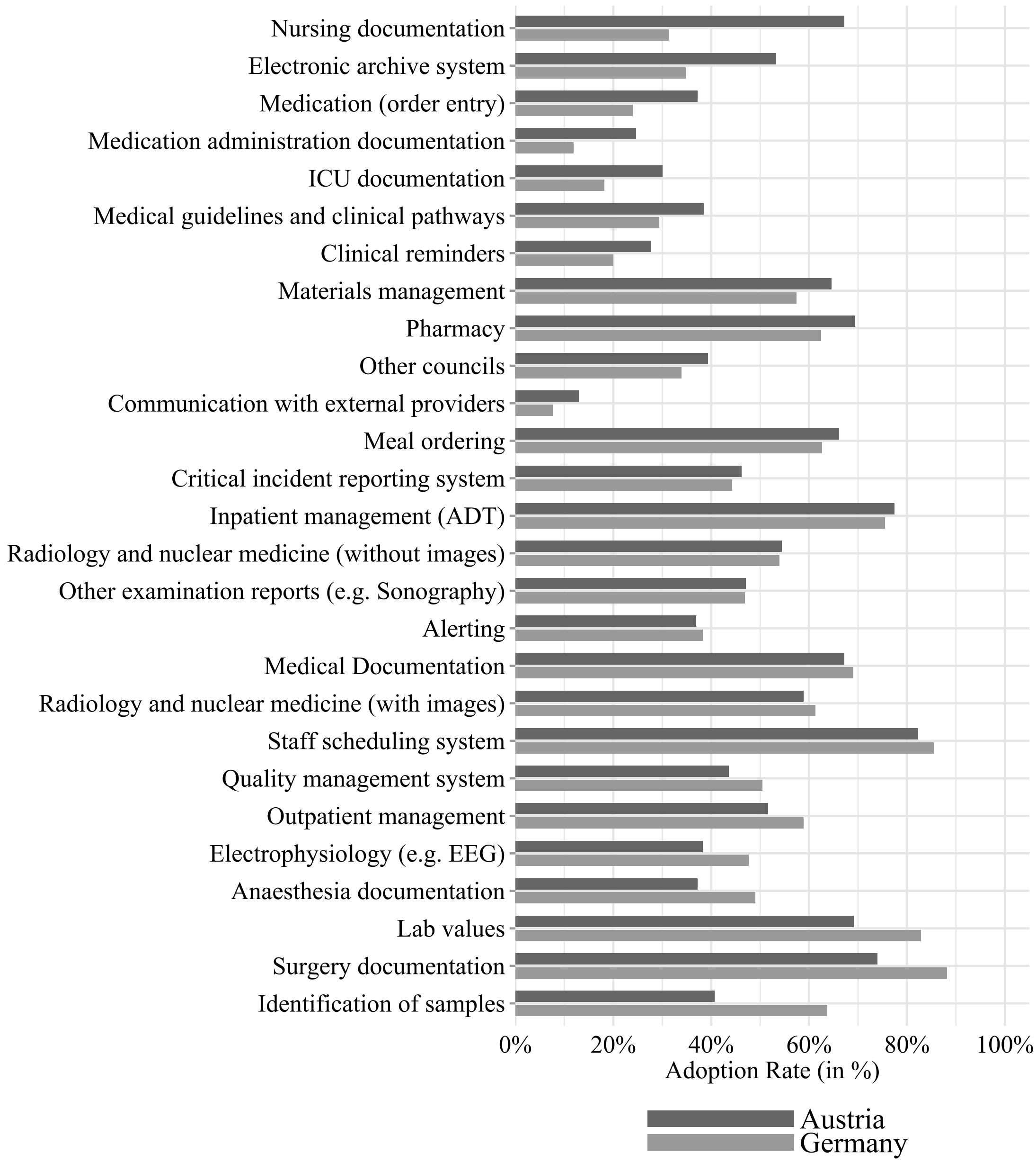

Figure 2: Adoption rates (implemented in at least on unit) for 27 IT functions clustered into 6 groups (sorted by size of difference within the groups starting with the largest positive difference between Austria and Germany in each group), k denotes the number of IT functions within this group.

The aggregated WCS sub-score "IT functions", which provided an integrated view on all IT functions, yielded an arithmetic mean of 57,9 (±18.8, n=70) for Austrian hospitals and of 52,3 (±12,6, n=464) for German hospitals. This indicated a higher level of adoption of IT functions in Austrian hospitals compared to German hospitals.

In order to explain the variance of this score a stepwise forward multiple linear regression analysis was performed. The two countries differed significantly (p = 0.027) (Tab. 3). "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 "size" (p = 0.000) and "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” (Tab. 3).

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

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 functions” was similar for both countries: more innovative hospitals had higher scores than less innovative ones as shown in the two univariate linear regression analyses (Fig. 3). However, Austrian hospitals had significantly higher innovation value ($\bar{x}$= 6.9 ±2.1; n=60) than German hospitals ($\bar{x}$ = 5.9 ±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).

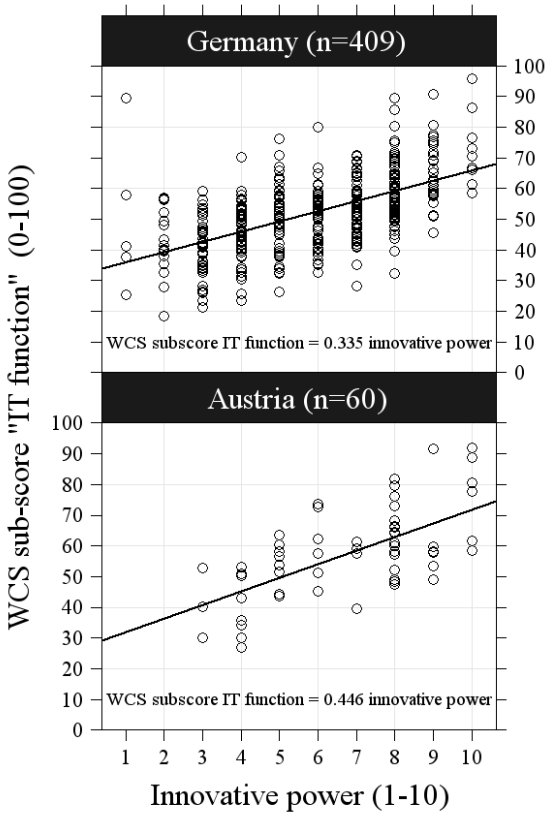

Figure 3: Scatterplot “innovative power” of the organisation perceived by the DoNs versus WCS sub-score “IT functions” for both countries

IT adoption: adjusted “perceived technical availability” for individual IT functions

Based on the knowledge that “innovative power”, “hospital size” and “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 firstly of the two demographic variables only (stage 1) and secondly of the two demographic variables plus “innovative power” (stage 2). Knowing that the two samples differed significantly with regard to hospital ownership this variable was included as third demographic factor for adjustments in both stages.

The adjustment for demographic variables (all values of stage 1 adjustment see Appendix D) led to a significant difference between the countries for “identification of samples” (OR = 0.39), showing that Germany had more systems available. 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),

Adjusting also for “innovative power” (all values of stage 2 adjustment see Appendix D) had no major effect on “nursing documentation” (OR = 4.76) and “ICU documentation” (OR = 2.63), which still were significantly more likely in Austria than in Germany. The significant higher values in Austria for “medication administration documentation”, “electronic archive” and “medication”, however, faded after stage 2 adjustment. The result for the IT function “identification of samples” (OR = 0.35) did not change with regard to its appraisal of significance. All p-values had been corrected for multiple testing.

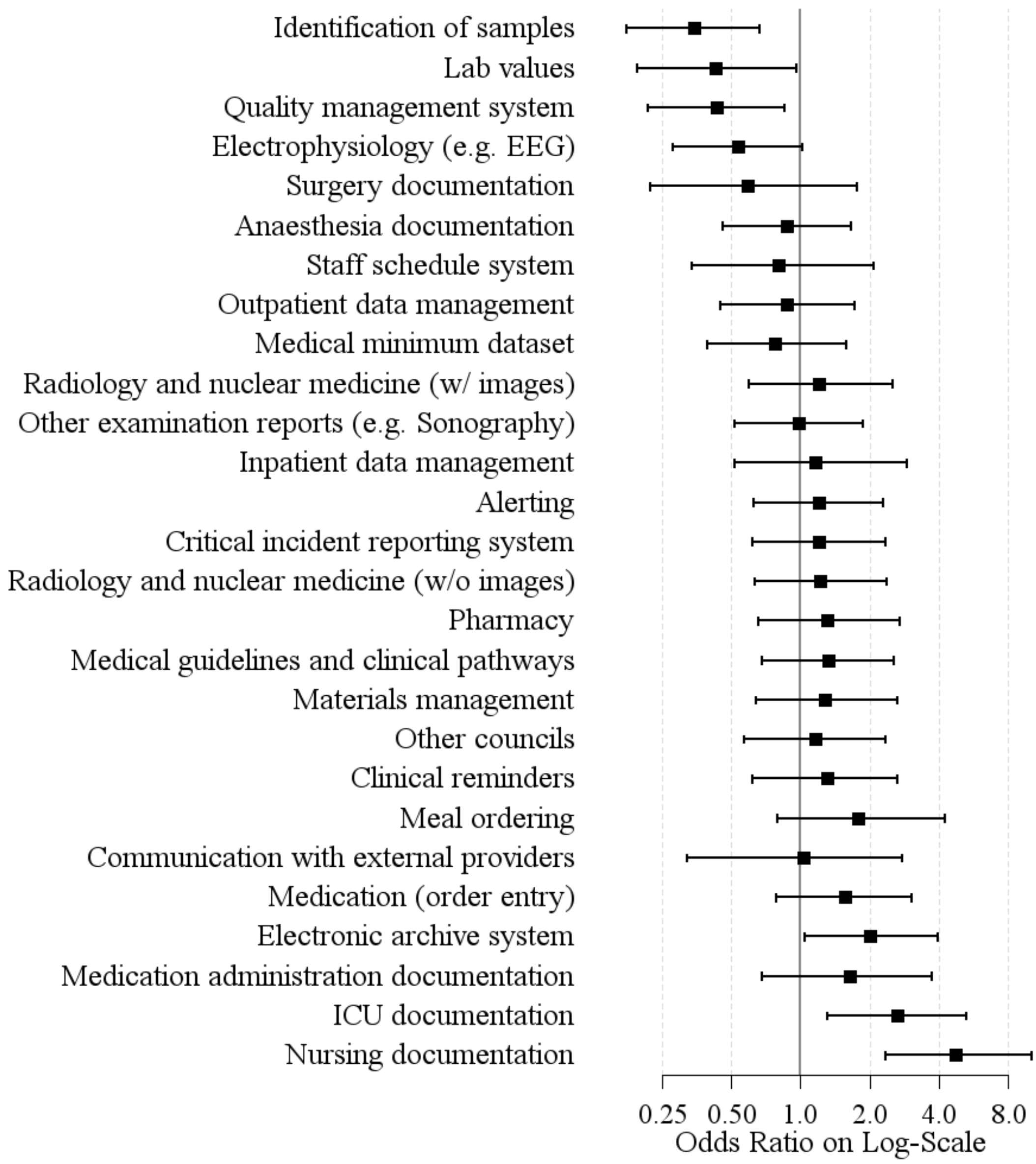

Figure 4: Left: adjusted OR values and 95% CI for demographic variables (stage 1), Right: adjusted OR and 95% CI values for demographic variables and “innovative power” (stage 2). Austria served as reference category in the logistic regression: OR > 1 indicates a greater chance that an IT function is implemented in Austrian hospitals than in German ones. For example, having implemented a nursing documentation system is 4.76 times more likely in Austria than in Germany (after adjusting for hospital demographics and “innovative power”).

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" were significantly better available in Austria than in Germany. This shows that differences between both countries persisted over the years. Our findings of the significantly higher composite sub-score "IT functions" 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 functions" but could not explain the difference between the two countries. This result matches other findings [14,15,18] but contradicts the literature with regard to the effect of "ownership" and "teaching status". The correlation between these two variables and "hospital size" may explain this result [14]. In both countries teaching hospitals and not for profit hospitals tend to be 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 functions", 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 impact of "innovation power" was definitely stronger in Austria than in Germany. The mechanism of action, hereby, seemed to operate selectively on certain IT functions in particular "medication", "medication administration record" and "electronic archive" as the difference of the adjustment from stage 1 to stage 2 demonstrated. Possible reasons for this mechanism are discussed below.

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.

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 hint to the fact that there is more money in the 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](BRD 2009) 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].

Conclusions

We conclude, that 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 directly 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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Beitrag 10: Zwischen Schattendasein, Governance und Entrepreneurship - Eine empirische Bestandsaufnahme zum Professionalisierungsgrad des IT Managements in deutschen Krankenhäusern

Titel	Zwischen Schattendasein, Governance und Entrepreneurship - Eine empirische Bestandsaufnahme zum Professionalisierungsgrad des IT Managements in deutschen Krankenhäusern
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Tabelle 11. Überblick Beitrag 10

Zwischen Schattendasein, Governance und Entrepreneurship - Eine empirische Bestandsaufnahme zum Professionalisierungsgrad des IT-Managements in deutschen Krankenhäusern

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Abstract. Bei der Umsetzung der digitalen Transformation bewegt sich das IT-Management in Krankenhäusern in einem Spannungsfeld aus historisch-kulturellen Vorbedingungen und den besonderen Herausforderungen wissensintensiver Expertenorganisation. Um zu untersuchen, wie professionell das IT-Management vor diesem Hintergrund ist, wurde in der vorliegenden Studie der Professionalisierungsgrad des IT-Managements als Beschreibungsgröße vorgeschlagen. Darüber hinaus wurden Ausprägungen der IT-Governance und des IT-Entrepreneurships als mögliche Determinanten des Professionalisierungsgrades konzeptionalisiert. Ein entsprechend aufgestelltes, hypothesengeleitetes Untersuchungsmodell wurde anhand der Daten von 164 CIOs deutscher Krankenhäuser überprüft. Die Ergebnisse der Studie deuten auf Professionalisierungspotenziale des IT-Managements im strategischen und evaluierenden Bereich hin. Etablierte Kommunikationskanäle zwischen CIO und Krankenhausleitung sowie eine ausgewiesene IT-Budgetverantwortungen wirkten sich positiv auf den Professionalisierungsgrad aus. Zudem Das agierte das IT-Management umso professioneller, je stärker der IT-Entrepreneurship auf organisatorischer und individueller Ebene ausgeprägt war. Die Ergebnisse können den theoretischen Erkenntnisstand über die Wirkungsweise von IT-Governance und IT-Entrepreneurship erweitern und auf ähnliche, wissensintensive Expertenorganisationen übertragen werden.

Keywords: IT-Management, Krankenhaus, CIO, Governance, Entrepreneurship

1 Einleitung

Die digitale Transformation birgt vielfältige Potenziale für eine Effizienz- und Qualitätssteigerung der Gesundheitsversorgung [1]. Zentrale Akteure innerhalb des Versorgungsgeschehens sind Krankenhäuser, die alleine im Jahr 2014 etwa neunzehn Milliarden Gesundheitsdienstleistungen erbracht haben [2]. Die Digitalisierung der hierfür notwendigen krankenhausinternen Abläufe soll die Planung und Koordination der Behandlung effizienter gestalten, die Informationstransparenz klinischer Prozesse erhöhen und den Zugang zu medizinischem Wissen vereinfachen [3]. Die Digitalisierungsmaßnahmen reichen dabei von der Dokumentation des Behandlungsverlaufs, über die Befundanforderung und -rückmeldung, bis hin zum Aufbau von entscheidungsunterstützenden Systemen, Wissensdatenbanken und der elektronischen Patientenakte (EPA) [4]. Bei der Durchführung entsprechender Maßnahmen bewegt sich das zuständige IT-Management der Krankenhäuser in einem Spannungsfeld aus historisch-kulturellen Vorbedingungen und gesetzlichen sowie ökonomischen Rahmenbedingungen.

Krankenhäuser sind, historisch bedingt, durch linienförmige Organisationsstrukturen und starre Hierarchien geprägt [5]. Abstimmungen über interdisziplinäre, abteilungsübergreifende Abläufe, welche ein primäres Betätigungsfeld des IT-Managements darstellen [6], finden zumeist nur auf oberster Hierarchieebene, zwischen der ärztlichen, pflegerischen und kaufmännischen Krankenhausleitung (KHL), statt [7]. Hinzu kommt, dass die vorherrschende berufsständische Autonomie, insbesondere des ärztlichen Bereichs, zu Zieldivergenzen und einer Vermischung von zentralen und dezentralen Entscheidungen führen kann [5]. Entsprechend können IT-Vorhaben in Krankenhäusern selten per Mandat durchgesetzt werden, sondern sind auf langfristige Abstimmungsprozesse angewiesen [8,9]. Vor diesem Hintergrund steht das IT-Management vor der Herausforderung, hochkomplexe und wissensbasierte Behandlungsprozesse in geeigneter Form informationstechnologisch zu unterstützen [10]. Hierbei wird der Erwartungsdruck durch den exponentiell steigenden, medizinischen Wissenszuwachs zusätzlich erhöht [11]. Bei der Integration entsprechender Anwendungen sieht sich das IT-Management nicht selten mit veralteten, heterogenen Systemen konfrontiert [12]. Eine weitere krankenhausspezifische Herausforderung ergibt sich aus den diversen gesetzlichen Vorgaben und Normen (bspw. Basel II, Medizinprodukte-Gesetz), welche die Etablierung eines umfassenden Risikomanagements erfordern [13] und somit in ihrer Umsetzung umfangreiche personelle und finanzielle Ressourcen binden können. Schließlich herrscht in der Krankenhauslandschaft ein zunehmender Wettbewerb und ökonomischer Druck [5], wodurch sich konkrete Erwartungen an das IT-Management ergeben. So sollen einerseits Effizienzreserven identifiziert und ausgeschöpft werden (z.B. die Vermeidung von Doppeluntersuchungen), andererseits steht die IT als potenzieller Kostenfaktor selber auf dem Prüfstand [12].

Die beschriebenen Rahmenbedingungen stellen das IT-Management der Krankenhäuser vor ein Dilemma: Zum einen erfordern die vielfältigen, teilweise divergierenden Herausforderungen weitreichende Handlungsfreiräume auf operativer, taktischer und strategischer Ebene [10], auf der anderen Seite können insbesondere historisch, kulturell und ökonomisch bedingte Restriktionen diese Freiräume begrenzen [5].

Über die Handlungsfähigkeit des IT-Managements von Krankenhäusern, im Sinne von planenden, steuernden und überwachenden Aktivitäten [10], existieren bis dato keine empirisch fundierten Erkenntnisse. Vielmehr wird dieser Forschungsgegenstand bisher nur randläufig in Studien zur IT-Adoption und zur IT-Governance betrachtet [1,4,9,14,15]. In der vorliegenden Arbeit wird zur Beschreibung des Umfangs und des Formalisierungsgrades des IT-Managements der *Professionalisierungsgrad* als konzeptionelle Beschreibungsgröße vorgeschlagen. Die Studie folgt weiterhin der Annahme, dass Ausprägungen der IT-Governance und des IT-Entrepreneurships mögliche Einflussgrößen auf den Professionalisierungsgrad darstellen. Entsprechend wurde vor dem Hintergrund des krankenhausspezifischen Kontextes ein hypothesengeleitetetes Untersuchungsmodell entwickelt, auf Basis dessen folgende Forschungsfragen beantwortet werden sollen: (1.) Wie ausgeprägt ist der Professionalisierungsgrad des IT-Managements in den deutschen Krankenhäusern und (2.) inwiefern beeinflusst die Ausprägung der IT-Governance und des IT-Entrepreneurships den Professionalisierungsgrad?

Durch die Betrachtung der Krankenhäuser, welche stellvertretend für Expertenorganisationen besondere Anforderungen an das IT-Management stellen, soll die Beantwortung der Forschungsfragen das theoretische Verständnis über die Wirkungsweise von IT-Governance und IT-Entrepreneurship erweitern. Auf der anderen Seite sollen die Ergebnisse praktische Hinweise liefern, wie das IT-Management im Hinblick auf die Herausforderung der digitalen Transformation in den Krankenhäusern professionalisiert werden kann.

2 Konzeptionelle Entwicklung des Untersuchungsmodells

2.1 Professionalisierungsgrad des IT-Managements

Das IT-Management umfasst alle planerischen, steuernden und überwachenden Aktivitäten, welche im Bezug auf die IT-Ressourcen eines Unternehmens auf strategischer, taktischer und operativer Ebene durchgeführt werden [10]. Nach Weill [16] handelt es sich bei diesen Aktivitäten um die Durchführung IT-bezogener Entscheidungen. Der *Professionalisierungsgrad* des IT-Managements kann über den Umfang und den Formalisierungsgrad der durchgeführten IT-Managementhandlungen definiert werden [10,17]. Professionalität im IT-Management hat demnach eine *quantitative* und eine *qualitative* Dimension.

Zur Definition der quantitativen Dimension können normative Ansätze herangezogen werden [10,18]. Eine zentrale Aufgabe des strategischen IT-Managements ist die Entwicklung einer, mit der Krankenhausstrategie korrespondierenden IT-Strategie [10]. Idealerweise wird die IT-Strategie in eine Finanz- und Investitionsplanung und in ein längerfristiges Projektportfolio überführt [19]. Um den Beitrag der IT zur Erreichung der Unternehmensziele darstellen zu können, erfolgt weiterhin eine strategische Überwachung, bspw. in Form gezielter Evaluationen [10]. Auf taktischer Ebene umfasst das IT-Management alle Aktivitäten, die zur Überführung der IT-Strategie in erfolgreiche IT-Projekte notwendig sind [10]. Hierbei ergeben sich insbesondere Aufgaben rund um die Analyse, Auswahl, Spezifikation, Einführung und Evaluation neuer Systeme [18]. Die Aktivitäten des operativen IT-Managements beziehen sich schließlich auf den erfolgreichen Betrieb aller IT-Komponenten, welche an den klinischen und administrativen Krankenhausabläufen beteiligt sind (Infrastruktur und Netzwerke, Applikationsbetreuung und -wartung, Help- bzw. Servicedesk, etc.) [10].

Die qualitative Dimension des Professionalisierungsgrades kann darüber definiert werden, inwiefern die einzelnen Handlungsweisen formalisiert bzw. standardisiert nach festgelegten Vorgehensweisen durchgeführt werden [12]. Durch die Formalisierung können die IT-Managementaktivitäten einerseits fortlaufend optimiert werden, indem sie an Best-Practice Lösungen ausgerichtet werden [9]. Andererseits ermöglicht die formalisierte Durchführung eine Orientierung der IT-Managementhandlungen an der Unternehmensstrategie [12]. Für die Formalisierung der Managementhandlungen werden in Krankenhäusern sowohl industrielle IT-Governance-Rahmenwerke (bspw. COBIT® oder ITIL®), als auch eigenentwickelte, bzw. generisch entstandene Rahmenwerke genutzt [9].

2.2 IT-Governance

IT-Governance schafft die Rahmenbedingungen für einen zielorientierten Betrieb der unternehmenseigenen IT-Ressourcen [16,20]. Gegenüber dem IT-Management befasst sich IT-Governance nicht mit der Durchführung IT-bezogener Entscheidungen, sondern mit den hierfür notwendigen Befugnissen und Verantwortlichkeiten [16]. IT-Governancemechanismen lassen sich in Strukturen, Prozesse und relationale Ansätze unterteilen [22]. Vor dem Hintergrund der krankenhausspezifischen Vor- und Rahmenbedingungen (vgl. Kap. 1) und im Hinblick auf den Professionalisierungsgrad des IT-Managements erscheinen insbesondere die *hierarchische Positionierung*, das *strategische IT-Alignment* und eine *ausgewiesene IT-Budgetverantwortung* des CIOs bzw. der IT-Abteilung relevante IT-Governancemechanismen darzustellen.

In Krankenhäusern werden abteilungs- und einrichtungsübergreifende Digitalisierungsmaßnahmen vorrangig auf oberen Hierarchiestufen abgestimmt, da sie über die bereichsbezogenen Entscheidungsräume des ärztlichen, pflegerischen und administrativen Bereichs hinausgehen [5,7]. Entsprechend kann eine hohe hierarchische Positionierung des CIOs (bspw. als Mitglied der KHL) die notwendigen Handlungsfreiräume, insbesondere für krankenhausweite Digitalisierungsprojekte, schaffen [9,23,24].

Neben der hierarchischen Einordnung wird die ganzheitlich Plan- und Steuerbarkeit der IT auch von der Ausprägung des strategischen IT-Alignments determiniert [9,10]. Unter IT-Alignment kann die wechselseitige Abstimmung von Strategien, Architekturen, Prozessen sowie Leistungen zwischen IT und (klinischen) Fachabteilungen verstanden werden [19,26]. In Krankenhäusern hat das IT-Alignment in den vergangenen Jahren verstärkt an Bedeutung gewonnen, da sich das Wirkungsfeld des IT-Managements mit zunehmenden informationstechnologischen Potenzialen von dem rein administrativen Funktionsbereich auf den medizinischen und pflegerischen Bereich ausweitet [1,4,10]. Die Synchronisierung von IT und Unternehmensstrategie kann sich zum einen in der Intensität des strategischen Austausches zwischen CIO und KHL und zum anderen in einer, mit der Krankenhausstrategie korrespondierenden IT-Strategie manifestieren [19,26]. Schließlich kann vermutet werden, dass eine ausgewiesene IT-Budgetverantwortung auf Seiten des CIOs bzw. der IT-Abteilung den Professionalisierungsgrad des IT-Managements erhöht, da hierdurch vermutlich langwierige investitionsbezogene Abstimmungsprozesse zwischen den Fachabteilungen verringert werden können [8].

Ausgehend von diesen Vorüberlegungen wird folgende Hypothese aufgestellt:

H1. Je ausgeprägter die IT-Governance, desto höher ist der Professionalisierungsgrad des IT-Managements in den Krankenhäusern.

2.3 IT-Entrepreneurship

Entrepreneurship beschreibt die Neugründung von Organisationen als Reaktion auf identifizierte Marktpotenziale und als Ausdruck spezifischer Gründerpersönlickeiten [27]. Jüngere Definitionen verstehen unter Entrepreneurship das unternehmerische Denken und Handeln innerhalb bestehender Organisation und beziehen sich dabei sowohl auf die Ausprägungen der Organisationskultur [28], als auch auf persönliche Eigenschaften der Organisationsmitglieder [29]. In der vorliegenden Studie wird zwischen *IT-Entrepreneurship-Kultur* und *IT-Entrepreneurship-Persönlichkeit* unterschieden.

Organisationen mit einer hohen IT-Entrepreneurship-Kultur erkennen und erschließen innovative, IT-bezogene Marktpotenziale im Vergleich zu ihren Mitbewerbern vergleichsweise frühzeitig als strategische Wettbewerbsvorteile [28]. Kennzeichnende Merkmale einer IT-Entrepreneurship-Kultur sind eine visionäre und innovative Grundausrichtung, eine vergleichsweise hohe organisatorische Flexibilität und eine Unternehmensleitung, die aktiv den Einsatz innovativer Technologien fördert [28,30]. Eine ausgeprägte IT-Entrepreneurship-Kultur kann sich in Krankenhäusern auf verschiedene Weise positiv auf den Professionalisierungsgrad des IT-Managements auswirken. Zum einen ist die Durchführung strategischer Managementaktivitäten in hohem Maße von der Unterstützung durch die KHL abhängig [8,14]. Andererseits profitiert sowohl die Implementierung als auch der operative Betrieb neuer IT-Lösungen von einer innovativen Grundhaltung und flexiblen Organisationsstrukturen, da hierdurch die Neugestaltung klinischer Arbeitsabläufe nicht nur ermöglicht, sondern im besten Fall auch aktiv von den klinischen Endanwendern eingefordert wird [8,15].

IT-Entrepreneurship-Persönlichkeiten zeichnen sich durch unternehmerisches Denken und Handeln hinsichtlich innovativer IT-Lösungen aus, womit sie nicht selten auch mangelnde Entscheidungsbefugnisse auf mittleren und unteren Hierarchiestufen ausgleichen [27,29]. Eigenschaften von IT-Entrepreneurship-Persönlichkeiten sind eine vergleichsweise hohe Risikobereitschaft, eine eigenständige und proaktive Vorgehensweise sowie eine hohe Partizipationsbereitschaft gegenüber IT-Anwendern [29,31]. In Krankenhäusern kann eine ausgeprägte IT-Entrepreneurship-Persönlichkeit des CIOs den Professionalisierungsgrad des IT-Managements auf verschiedene Weise positiv beeinflussen. Auf der einen Seite können risikoaffine und proaktiv agierende Persönlichkeiten vorherrschende Entscheidungsrestriktionen (vgl. Kap. 1) überwinden und somit zu einem innovativem IT-Betrieb beitragen [29-31]. Auf der anderen Seite kann das IT-Management vermutlich insbesondere in Expertenorganisationen wie Krankenhäusern von einem partizipativen bzw. anwenderorientierten Führungsstil des CIOs profitierten [8,15]. Dies zeigt sich exemplarisch an der Herausforderung, die oftmals hochkomplexen, wissensintensiven medizinischen Behandlungsprozesse in geeigneter Form durch IT zu unterstützen [6]. Gerade klinische Entscheidungen gelten aufgrund des Zusammenspiels von medizinischem Erfahrungswissen, individuellen Patientendaten und medizinischer Evidenzlage als schwer standardisierbar [11]. Entsprechend bedarf es für die Identifikation innovative IT-Lösungen, welche den Klinikern die aktuelle und relevante medizinische Evidenz störungsfrei im Kontext des jeweiligen Behandlungsgeschehens zur Verfügung stellen sollen, nicht nur eine proaktive und risikoaffine Persönlichkeit, sondern auch eine enge Zusammenarbeit zwischen IT-Management und klinischen Experten [6,10,14,18].

Ausgehend von diesen Vorüberlegungen wird folgende Hypothese aufgestellt:

H2. Je ausgeprägter der IT-Entrepreneurship, desto höher ist der Professionalisierungsgrad des IT-Managements in den Krankenhäusern.

2.4 Untersuchungsmodell

Zur Strukturierung des Forschungsvorhabens wurden die konzeptionellen Vorüberlegungen in ein hypothesengeleitetes Untersuchungsmodell überführt (Abb. 1). Die drei zentralen Beschreibungsgrößen des Modells wurden zweistufig angeordnet, da im Hinblick auf den Professionalisierungsgrad des IT-Managements von einem unabhängigen bzw. einem, sich reziprok ergänzendem Einfluss der IT-Governance und des IT-Entrepreneurships ausgegangen wurde. Neben den vorab konzeptionalisierten Beschreibungsgrößen umfasst das Modell Kontrollvariablen als konfundierende Merkmale.

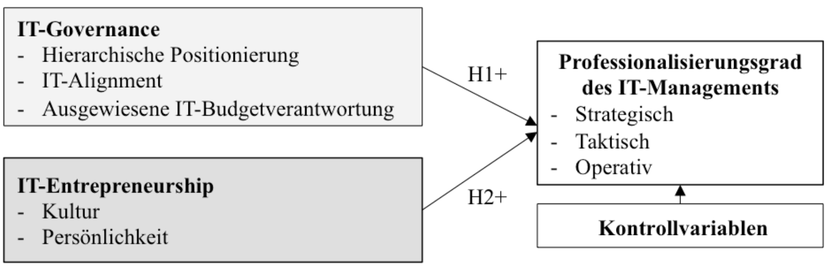

Abbildung 1: Untersuchungsmodell

3 Methode

3.1 Operationalisierung und Datenerhebung

Zur Beantwortung der Forschungsfragen wurde in Anlehnung an Köbler et al. [32] eine empirische Querschnittsuntersuchung als Datenerhebungsmethode ausgewählt. Der hierbei genutzte Fragebogen wurde in mehreren Schritten entwickelt.

In einem ersten, konzeptionellen Schritt wurden die Items für den Fragebogen aus der Literatur abgeleitet [9,10,12,16,18,22,27–31,33–35]. In einem zweiten Schritt wurden die identifizierten Items gemeinsam mit zwei CIOs auf die Übertragbarkeit auf deutsche Krankenhäuser überprüft und teilweise angepasst. Schließlich wurde der Fragebogen in einem Online-Erhebungstool umgesetzt und zwei Pretests unterzogen, in welchen die inhaltliche und technische Plausibilität überprüft wurde. An den Pretests beteiligte sich eine heterogene Gruppe aus vier zusätzlichen CIOs und sechs Wissenschaftlern. Insgesamt wurden 35 Items für die Überprüfung des Untersuchungsmodells entwickelt (vgl. Tab. 2).

Professionalisierungsgrad des IT-Managements: Die quantitative Dimension des Professionalisierungsgrades wurde in Anlehnung an Winter et al. [10] über die Anzahl der durchgeführten IT-Managementaktivitäten operationalisiert. Die qualitative Dimension wurde in Anlehnung an Schlegel et al. [12] über den Formalisierungsgrad der IT-Managementaktivitäten erfasst.

IT-Governance: In Orientierung an vergleichbare Studien [33,36] wurde die Ausprägung der IT-Governance sowohl über organisatorische, als auch über individuelle Eigenschaften operationalisiert. Um die hierarchische Einordnung des IT-Betriebes zu erfassen, wurde gefragt, ob der CIO Mitglied der KHL ist und ob die IT-Abteilung als Stabsstelle fungiert. Das strategische IT-Alignment wurde operationalisiert, indem zum einen die Intensität der strategischen Kommunikation zwischen CIO und KHL und zum anderen das Vorhandensein einer, mit der Krankenhausstrategie korrespondierenden IT-Strategie abgefragt wurden. Schließlich wurde erhoben, ob der CIO bzw. die IT-Abteilung über ein ausgewiesenes IT-Budget verfügen.

IT-Entrepreneurship: Zur Operationalisierung der IT-Entrepreneurship-Kultur wurden in Anlehnung an Bradley et al. [30] drei Items entwickelt, mit denen der Unterstützungsgrad durch die KHL, die Flexibilität der Organisationstruktur und die visionäre Ausrichtung innerhalb des Krankenhauses eingeschätzt werden konnten. Die IT-Entrepreneurship-Persönlichkeit wurde ebenfalls über drei Items operationalisiert, mit denen die proaktive Handlungsweise, die Risikoaffinität und die Partizipationsbereitschaft des CIOs erfasst wurden [31].

Kontrollvariablen: Insgesamt wurden sechs Kontrollvariablen als konfundierende Größen erfasst. Dies waren auf organisatorischer Ebene der Status eines Verbundkrankenhauses, der Status eines Universitätskrankenhauses, die Größe (Bettenzahl) sowie die Trägerschaft des Krankenhauses. Diese Merkmale wurden als positive Einflussgrößen auf die IT-Adoption von Krankenhäusern identifiziert [1,4,37] weshalb vermutet wurde, dass sie auch mit dem Professionalisierungsgrad des IT-Managements zusammenhängen können. Auf Ebene des CIOs wurde in Anlehnung an Smith et al. [36] die Betriebszugehörigkeit des CIOs (in Jahren) sowie in Anlehnung an Burke et al. [38] der akademische Grad (Hochschulabschluss) erhoben. So wurde davon ausgegangen, dass die Erfahrung und Beständigkeit einer Position, sowie die Qualifikation den Professionalisierungsgrad beeinflussen können.

Der Link zu dem Online-Fragebogen wurde in der Feldphase an 1284 CIOs deutscher Krankenhäuser verschickt. Die E-Mailadressen wurden in einer vorgeschalteten Internet- und Telefonrecherche erfasst. Die recherchierten CIOs waren insgesamt für 1675 Krankenhäuser zuständig. Von 305 Krankenhäusern konnten keine Adresse ermittelt werden, da entweder die Position des CIOs nicht existierte, die IT Organisation extern durchgeführt wurde oder in der Recherche keine Auskunft gegeben wurde. Der Erhebungszeitraum erstreckte sich von Februar bis April 2016. In diesem Zeitraum wurden drei Nachfassaktionen durchgeführt.

3.2 Stichprobe

Insgesamt nahmen 188 CIOs an der Umfrage teil, von denen nach einer Vollständigkeits- und Plausibilitätsprüfung 24 Bögen aussortiert wurden. Die verbliebenen 164 auswertbaren Datensätze entsprachen einer Rücklaufquote von 12,8%. In der finalen Stichprobe waren 45,1% der Teilnehmer für mehr als ein Krankenhaus zuständig, sodass die teilnehmenden CIOs insgesamt 397 Krankenhäuser betreuten ($\bar{x}$=2,4; SD=4,6). Die durchschnittliche Betriebszugehörigkeit der CIOs lag bei 11,7 Jahren (SD=7,9). Über einen Hochschulabschluss verfügten 58,5%. Zur Überprüfung der Repräsentativität wurde die Stichprobe in Anlehnung an Köbler et al. [32] nach Größe und Trägerschaft segmentiert und mit der Population deutscher Krankenhäuser verglichen [2] (vgl. Tab.1). Gegenüber der Grundgesamtheit waren kleinere Krankenhäuser mit weniger als 200 Betten leicht unterrepräsentiert und mittlere und größere Krankenhäuser entsprechend überrepräsentiert. Hinsichtlich der Trägerschaft waren private Einrichtungen unterrepräsentiert und öffentliche- sowie freigemeinnützige Krankenhäuser überrepräsentiert.

Tabelle 1: Gegenüberstellung von Stichprobe und Population [2]

Trägerschaft	*unter 200 Betten*	*200 bis 799 Betten*	*800 Betten und mehr*	*Stichprobe*	*Population*
Öffentlich	21,4%	58,9%	19,6%	34,1%	29,7%
Privat	63,2%	26,3%	10,5%	11,6%	35,1%
Frei / Gemeinnützig	44,9%	55,1%	0,0%	54,3%	35,1%
Studienstichprobe	39,0%	53,0%	7,9%	100,0%	
N	64	87	13	164	
Population	56,2%	39,1%	4,7%	100,0%	
N	1113	774	93		1980

In Tabelle 2 werden die deskriptiven Statistiken der Items dargestellt, welche für die Operationalisierung der Beschreibungsgrößen im Untersuchungsmodell genutzt wurden.

Tabelle 2: Deskriptive Statistiken (WB=Wertebereich; n=164)

	Items	WB	$\overline{x}$	SD
strat. IT-Mgmt	Strategische Überwachung (gezielter Evaluationen inkl. Kennzahlenerhebung)[1]	1-3	1,37	0,67
	Erstellung eines Projektportfolios (für ca. 12 Jahre) [1]	1-3	1,55	0,69
	Entwicklung einer mit der Krankenhausstrategie korresp. IT-Strategie[1]	1-3	1,58	0,73
	Strategische Steuerung in Form der Priorisierung und Initiierung von Projekten[1]	1-3	1,76	0,68
	Längerfristige Finanz und Investitionsplanung[1]	1-3	1,77	0,67
takt. IT-Mgmt	Systemevaluation (Informationsbeschaffung, -aufbereitung und -präsentation) [1]	1-3	1,68	0,54
	Systemspezifikation (Beschreibung des SOLL-Zustands, Pflichtenhefts, etc.) [1]	1-3	1,80	0,43
	IT-Projektmanagement (Projektplanung, -begleitung und -abschluss) [1]	1-3	1,85	0,49
	Systemeinführung (Einführungsstrategie, Adaptierung, Mitarbeiterschulung) [1]	1-3	1,88	0,44
	Systemanalyse und -bewertung (bezogen auf den IST-Zustand) [1]	1-3	1,91	0,42
	Systemauswahl (Marktanalyse, Ausschreibung, Angebotsvergleich) [1]	1-3	1,94	0,41
operat. IT-Mgmt	Durchführung eines IT-bezogenen Rechnungswesen[1]	1-3	1,91	0,69
	Durchführung eines IT-bezogenen Vertragsmanagement[1]	1-3	1,93	0,70
	Schulungen bzw. Trainings klinischer Endanwender[1]	1-3	2,04	0,64
	Betrieb des Helpdesk / Servicedesk[1]	1-3	2,14	0,59
	Applikationsbetreuung und -wartung[1]	1-3	2,21	0,51
	Steuerung und Überwachung von Infrastruktur und Netzwerken[1]	1-3	2,23	0,50
IT-Governance	Intensität strategische Kommunikation[2]	0-10	0,05	0,23
	Existenz einer, mit der Krankenhausstrategie korrespondierenden IT-Strategie[3]	0-1	0,18	0,38
	CIO ist Mitglied der Krankenhausleitung[3]	0-1	0,05	0,23
	IT-Abteilung ist als Stabsstelle eingesetzt[3]	0-1	0,18	0,38
	CIO verfügt über ein ausgewiesenes IT-Budget[3]	0-1	0,26	0,44
	IT-Abteilung verfügt über ein ausgewiesenes IT-Budget[3]	0-1	0,76	0,43
IT-Entrep.	Als CIO muss ich mich intensiv mit den Bedürfnissen der Anwender befassen[4]	1-4	2,54	0,84
	Als CIO arbeite und entscheide ich weitestgehend selbstbestimmt[4]	1-4	2,29	0,66
	Als CIO muss ich mich auch auf neue, nicht bewährte Lösungen einlassen[4]	1-4	1,98	0,59
	Unsere Krankenhausleitung fördert aktiv innovative IT-Lösungen[4]	1-4	2,68	0,80
	Unser Krankenhaus ist bzgl. des Einsatzes innovativer IT sehr flexibel[4]	1-4	2,77	0,78
	In unserem Krankenhaus herrscht eine Zukunftsvision, die auch die IT umfasst[4]	1-4	2,81	0,80

[1] 1=„keine Durchführung“; 2=„nicht-formalisierte Durchführung“; 3=„formalisierte Durchführung in Anlehnung an eigens entwickelte oder industrielle IT-Governancerahmenwerke“,
[2] Anzahl von häufig zw. CIO und KHL ausgetauschter, strategischer Informationen. Mehrfachauswahl von zehn Informationstypen, z.B. „IT-relevante Krankenhausziele“, „Sicherheitskonzept“, „Prozesse“
[3] 0=„Nein“; 1=„Ja“
[4] 1=„Stimme überhaupt nicht zu“; 2=„Stimme eher nicht zu“; 3=„Stimme eher zu“; 4=„Stimme voll und ganz zu“

3.3 Datenanalyse

Um die Annahmen des Untersuchungsmodells zu überprüfen, wurde eine multiple Regressionsanalyse mit SPSS23® durchgeführt. Multiple Regressionsanalysen eignen sich als hypothesenprüfende Verfahren, da sie den Einfluss mehrerer unabhängiger Variablen (Prädiktoren) auf eine abhängige Variable (Kriterium) testen [39].

Als Kriterium diente der *Professionalisierungsgrad des IT-Managements*. Zur Quantifizierung des Professionalisierungsgrades wurde ein gewichteter Summenscore gebildet, indem pro durchgeführte IT-Managementaktivität ein Punkt und pro formalisiert durchgeführter IT-Managementaktivität 1,5 Punkte vergeben wurden.[1] Der gewichtete Summenscore wurde skaliert, sodass der Professionalisierungsgrad des IT-Managements in einem Wertebereich von 0 bis 100 Punkten lag.

Um das Untersuchungsmodell zu überprüfen, wurden fünf Merkmale zur Beschreibung der IT-Governance[2], zwei Merkmale zur Beschreibung des IT-Entrepreneurships sowie sechs Kontrollvariablen als konfundierende Größen in das Modell eingeschlossen (vgl. Kap. 3.1). Zur Quantifizierung der *IT-Entrepreneurships-Kultur* und *-Persönlichkeit* wurden Summenscores gebildet, indem jeweils der Zustimmungsgrad zu den drei aufgestellten Aussagen (vgl. Tab. 2) aufaddiert wurde.

Für die statistischen Analysen wurden fehlende Werte durch Mittelwerte ersetzt. Zur Überprüfung der Modellvoraussetzungen wurde auf Homoskedastizität sowie auf Normalverteilung der Residuen getestet. Zur Prüfung auf Multikollinearität wurden Toleranzwerte sowie der Variance Inflation Factor (VIF) berechnet [39]. Zudem wurden die signifikant in dem Modell verbliebenen Prädiktoren korreliert.

4 Ergebnisse

Von maximal 100 Punkten, die für den Professionalisierungsgrad des IT-Managements erreicht werden konnten, erzielten die befragten Einrichtungen durchschnittlich 42 (SD=14; n=164). Der niedrigste Wert lag bei 15, der höchste bei 100 Punkten. Nur knapp jedes fünfte teilnehmende Krankenhaus erreichte einen Wert über 50 (19,5%; n=164). Strategische IT-Managementaktivitäten wurden gegenüber operativen und taktischen Managementaktivitäten vergleichsweise selten durchgeführt. Dies galt insbesondere für die strategische Überwachung, aber bspw. auch für die Entwicklung von längerfristigen IT-Projektportfolios und für die IT-Strategieplanung (vgl. Tab. 2). Sowohl im strategischen, als auch im taktischen und operativen Bereich wurden evaluierende bzw. überwachende IT-Managementhandlungen im Gegensatz zu planenden und ausführenden Aktivtäten seltener durchgeführt (vgl. Tab. 2).

In Tabelle 3 werden die Koeffizienten der Prädiktoren im Regressionsmodell, gegliedert in Anlehnung an die Operationalisierung der Beschreibungsgrößen (vgl. Kap. 3.1), dargestellt. Von den 13 Prädiktoren, welche in das Modell eingeschlossen wurden, ergaben sich neun signifikante Beta-Koeffizienten (vgl. Tab. 3). Zusammengenommen erklärten die eingeschlossenen Prädiktoren 47,0% der Varianz des Professionalisierungsgrades (korr. R^2). Drei der fünf überprüften IT-Governancemerkmale zeigten einen signifikant positiven Einfluss auf den Professionalisierungsgrad. Ebenfalls wirkte sich die IT-Entrepreneurship-Kultur und -Persönlichkeit signifikant posi-

[1] Die moderierende Gewichtung folgt der Annahme, dass formalisiert durchgeführte Managementaktivitäten im Hinblick auf den Professionalisierungsgrad nicht zwangsläufig doppelt so hoch gewertet werden können, wie ad-hoc durchgeführten Aktivitäten, da die Aktivität an sich der wesentliche Aspekt ist.

[2] Die Variable "CIO ist Mitglied der KHL" wurde aufgrund der ungleichen Verteilung der Merkmalsausprägungen (5% zu 95%) aus der Regressionsanalyse herausgenommen.

tiv auf den Professionalisierungsgrad aus. Auch der Status eines Universitätsklinikums und der des Verbundkrankenhauses zeigten einen signifikant positiven Einfluss.

Die Residuen waren normalverteilt und Homoskedastizität lag nicht vor, sodass die Modellvoraussetzungen erfüllt waren. Die errechneten Korrelationsstatistiken gaben keine Hinweise auf Multikollinearität (vgl. Tab. 3). In Tabelle 4 werden die Korrelationen der signifikanten Prädiktoren in Form einer Korrelationsmatrix dargestellt. Die Korrelation der Prädiktoren weisen auf schwache, positive Korrelationen zwischen einzelnen Prädiktoren hin, wobei die „Intensität der strategischen Kommunikation" mit drei signifikanten Korrelationskoeffizienten am häufigsten korrelierte (vgl. Tab. 4).

Tabelle 3. Koeffizienten der Prädiktoren im Regressionsmodell (n=164)

Prädiktor	*Beta*	*Sig.*	*Toleranz*	*VIF*
Intensität der strat. Kommunikation	0,205	0,002	0,798	1,254
Existenz eines IT-Strategie	0,062	0,329	0,803	1,246
IT-Abteilung ist Stabsstelle	0,030	0,625	0,877	1,140
CIO verfügt über IT-Budget	0,231	0,000	0,933	1,071
IT-Abteilung verfügt über IT-Budget	0,173	0,004	0,906	1,104
IT-Entrepreneurship-Kultur	0,192	0,004	0,841	1,150
IT-Entrepreneurship-Persönlichkeit	0,224	0,000	0,893	1,120
Status eines Universitätskrankenhauses	0,147	0,210	0,822	1,217
Status eines Verbundkrankenhauses	0,247	0,000	0,902	1,108
Trägerschaft (Privat)	-0,850	0,153	0,939	1,064
Größe (Bettenzahl)	0,760	0,271	0,682	1,467
Betriebszugehörigkeit (in Jahren)	-0,187	0,002	0,916	1,092
CIO hat Hochschulabschluss	0,100	0,094	0,924	1,082

Tabelle 4. Korrelation der signifikanten Prädiktoren (*p<0,05; n=164)

		1	2	3	4	5	6	7	8
1	Intensität strat. Kommunikation	1,000	.	.	.	.	.	.	.
2	CIO verfügt über IT-Budget	0,131	1,000	.	.	.	.	.	.
3	IT-Abt. verfügt über IT-Budget	0,149	0,113	1,000	.	.	.	.	.
4	IT-Entrep.-Kultur	0,377*	0,048	0,254*	1,000	.	.	.	.
5	IT-Entrep.-Persönlichkeit	0,205*	0,101	0,127	0,172*	1,000	.	.	.
6	Universitäts-krankenhaus	0,177*	0,196*	0,085	0,058	0,199*	1,000	.	.
7	Verbund-krankenhaus	-0,052	0,028	-0,014	-0,189*	0,036	-0,198*	1,000	.
8	Betriebs-zugehörigkeit	-0,057	0,024	-0,012	0,153	0,096	-0,147	0,079	1,000
	Hochschul-Abschluss	0,082	0,108	0,098	-0,065	0,037	0,214*	0,029	-0,098

5 Diskussion

Ein professionell agierendes IT-Management gilt als Dreh- und Angelpunkt für eine erfolgreiche Umsetzung der digitalen Transformation [4,10,19,32]. Vor diesem Hintergrund erscheint es umso bemerkenswerter, dass bis dato keine empirisch fundierten Erkenntnisse darüber existieren, wie professionell das IT-Management in Krankenhäusern tatsächlich ist und wodurch der Professionalisierungsgrad determiniert wird. Um diese Forschungslücke zu schließen, wurde in der vorliegenden Studie ein hypothesengeleitetes Untersuchungsmodell entwickelt und anhand der Daten von 164 CIOs überprüft.

Die Ergebnisse der Studie deuten auf diverse Professionalisierungspotenziale des IT-Managements hin. So müsste ein Großteil der befragten Krankenhäuser die IT-Strategieplanung intensivieren und entsprechende IT-Vorhaben konsequent in adäquate Finanz- und Investitionsplanungen sowie in längerfristige Projektportfolios überführen, wenn sie die Digitalisierungspotenziale proaktiv nutzen wollen [10,19]. Zudem müsste der Einsatz fortlaufender Evaluierungsmaßnahmen wie bspw. Systemanalysen, Anwenderbefragungen oder IT-Benchmarks verstärkt fokussiert werden, um den Fortschritt des digitalen Wandels überwachen und seinen Wertbeitrag transparent darstellen zu können [9,10,13].

Bei entsprechenden Professionalisierungsbemühungen sieht sich das IT-Management der Krankenhäuser mit unterschiedlichen Herausforderungen konfrontiert [5,7-9,12-14]. Vor diesem Hintergrund wurde die Annahme getroffen, dass eine ausgeprägte IT-Governance sowie ein hoher IT-Entrepreneurship den Professionalisierungsgrad positiv beeinflussen. Die Ergebnisse der Studie konnten diese Annahmen weitestgehend bestätigen. So scheint sich der intensive Austausch zwischen CIO und KHL positiv auf den Professionalisierungsgrad des IT-Managements auszuwirken. Dies gilt auch für eine ausgewiesene IT-Budgetverantwortung des CIOs bzw. der IT-Abteilung. Der Einfluss der hierarchischen Positionierung des CIOs konnte aus methodischen Gründen nicht überprüft werden. Jedoch zeigten die Ergebnisse, dass das IT-Management in den meisten Krankenhäusern auf mittleren und unteren Hierarchiestufen eingeordnet ist. Die Wirkungsweise der betrachteten IT-Governancemechanismen sollten im Zusammenhang mit dem ebenfalls betrachteten IT-Entrepreneurship interpretiert werden. So deuten die Ergebnisse darauf hin, dass der Professionalisierungsgrad des IT-Managements durch eine ausgeprägte Unterstützung der KHL positiv beeinflusst wird. Darüber hinaus scheint ein professionell agierendes IT-Management mit einer visionären Grundhaltung und flexiblen Organisationsstrukturen einherzugehen. Schließlich konnte durch die Ergebnisse gezeigt werden, dass sich eine ausgeprägte Entrepreneurship-Persönlichkeit des CIOs positiv auf den Professionalisierungsgrad des IT-Managements auswirkt. So kann vermutet werden, dass CIOs auf mittleren und unteren Hierarchiestufen mangelnde Entscheidungsbefugnisse durch unternehmerisches Denken und Handeln ausgleichen [27,29]. Darüber hinaus scheint das IT-Management insbesondere in wissensintensiven Expertenorganisationen wie Krankenhäusern von einem anwenderorientierten Führungsstil des CIOs zu profitierten [8,15].

Die vorliegende Studie liefert erste Hinweise auf wesentliche Begleitumstände und Vorbedingungen eines professionellen IT-Managements. Hierdurch erhalten Krankenhäuser empirisch fundierte Hinweise für eine erfolgreiche Umsetzung der digitalen Transformation. Insbesondere die Rolle einer ausgeprägten Entrepreneurship-Persönlichkeit des CIOs kann einen Ansatz für weitergehende Forschungsarbeiten liefern. In einem ersten Schritt könnte eine reliable und valide Operationalisierung des Konstrukts, bspw. durch faktoranalytische Verfahren fokussiert werden. Weiterhin könnten Folgestudien die Wechselwirkung von IT-Governance und IT-Entrepreneurship durch Interaktionstests näher spezifizieren. Auch wäre es von Interesse, die IT-Performance der Krankenhäuser in einem erweiterten, mehrstufigen Untersuchungsmodell als zusätzliche Zielgröße zu berücksichtigen. Die IT-Performance könnte über die IT-Unterstützung klinischer Prozesse operationalisiert werden. Schließlich könnte die Übertragbarkeit der Ergebnisse auf andere Betätigungsfelder des IT-Managements, insbesondere auf das Feld von wissensintensiven Expertenorganisationen (z.B. Hochschulen) überprüft werden.

6 Limitation

Bei der Interpretation der Studienergebnisse müssen mehrere Limitationen berücksichtigt werden. Zum einen steht die betrachtete Stichprobe nicht repräsentativ für die Grundgesamtheit der deutschen Krankenhäuser. Kleinere und nicht private Einrichtungen waren unterrepräsentiert. Die Faktoren zur Beschreibung des Professionalisierungsgrades und des Entrepreneurships wurden zwar inhaltlich validiert, jedoch nicht auf Reliabilität überprüft. Die vorgenommene, moderierende Gewichtung folgte zudem ausschließlich inhaltlichen Erwägungen. Weiterhin wurde die IT-Governance größtenteils über binäre Merkmale operationalisiert. Zukünftige Ansätze sollten hier, komplementär zur Operationalisierung von IT-Entrepreneurship, validierte Item-Skalen nutzen. Zwischen den einzelnen Prädiktoren zeigten sich schwache, jedoch signifikante positive Korrelationen. Obwohl dies die Interpretierbarkeit der Ergebnisse im Hinblick auf die zusätzlich berechneten Multikollinearitätstatistiken nicht schwächt, sollten zukünftige Ansätze eine überschneidungsfreie Operationalisierung adressieren. Auch aus der Nutzung des gewählten Analyseverfahrens ergeben sich Limitationen. Regressionsanalysen eignen sich insbesondere für die Überprüfung prozesshafter Modelle mit einseitigen Abhängigkeiten zwischen den Merkmalen. Diese kausalen Beziehungen spiegeln die Realität des betrachteten Untersuchungsfeldes jedoch nur bedingt wider, da sich IT-Governance und das IT-Management vermutlich rekursive beeinflussen. Schließlich berücksichtigt das Modell keine Strukturbrüche zwischen den individuellen Merkmalen des CIOs und den Merkmalen der Organisation. Zukünftige Ansätze sollten daher auf komplexere Analyseverfahren, wie bspw. Mehrebenenmodelle oder Strukturgleichungsverfahren zurückgreifen.

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Beitrag 11: Entwicklung eines Datenmodells für ein umfassendes Forschungsdatenmanagement zur flexiblen Analyse longitudinaler Daten

Titel	Entwicklung eines Datenmodells für ein umfassendes Forschungsdatenmanagement zur flexiblen Analyse longitudinaler Daten
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Tabelle 12. Überblick Beitrag 11

Entwicklung eines Datenmodells für ein umfassendes Forschungsdatenmanagement zur flexiblen Analyse longitudinaler Daten

Jan-Patrick Weiß[1], Jens Rauch[2], Jens Hüsers[3], Jan-David Liebe[4], Frank Teuteberg[5] und Ursula Hübner[6]

Abstract: Forschungsdatenbanken dienen als gemeinsame Datenbasis für heterogene Datensätze unterschiedlicher Wissenschaftler, um neue Forschungsansätze, Ideen oder Fragestellungen im Forschungsprozess zu identifizieren und zu analysieren. Klassische Datenmodellierungs-Ansätze wie das dimensionale Modell oder das Entity-Attribute-Value (EAV) Modell erweisen sich entweder als unflexibel hinsichtlich neuer Anforderungen und der Erweiterung um neue Datenquellen oder erschweren longitudinale Analysen. In diesem Artikel wird ein grundlegendes Systemdesign für sich häufig ändernder Forschungsdaten vorgestellt und als erster Meilenstein die Implementation des Datenmodells fokussiert. Das EAV-Modell wurde hierzu um das Data-Vault-Modell erweitert. Dieser kombinierte Ansatz ermöglicht die Historisierung beliebiger Merkmalsausprägungen und die Erweiterung um neue Merkmale aus weiteren Datenquellen.

Keywords: Datenmanagement, Datenmodell, longitudinale Daten, Forschungsdatenbank, Data-Vault-Modell

1 Einleitung

Häufig werden in Forschungsprojekten heterogene Daten gesammelt oder erstmalig erzeugt [Po15], [Th14]. Durch eine gemeinsame Datenbasis für unterschiedliche Wissenschaftler können darüber neue Forschungsansätze, Ideen oder Fragestellungen im Rahmen des Forschungsprozesses identifiziert [He09] und analysiert werden. Das Forschungsdatenmanagement sichert somit den langfristigen Austausch von Informationen für zukünftige Forschungsfragen [Me12]. Im Gesundheitswesen hat sich in den letzten Jahren das Konzept des „lernenden Gesundheitssystems“ entwickelt, das die Nutzung von Routinedaten für die Forschung vorsieht [OAM07] und diese bei Bedarf mit Forschungsdaten verknüpft. Dabei soll über eine zentrale oder vernetzte Plattform ein Informationsaustausch zwischen Forschung und Praxis gefördert werden, sodass beispielsweise Sekundärdaten weiteren Anwendungsfällen zugeführt werden und das erarbeitete Wissen unter den unterschiedlichen Stakeholdern geteilt wird [FWB10]. Die verteilten, unterschiedlichen, internen und externen Datenquellen führen jedoch zu informationstechnologischen Barrieren [LBK07]. Für einen effektiven und effizienten Informationsaustausch, müssen im Prozess des Forschungsdatenmanagements die Datenbestände integriert sowie konsistent und strukturiert persistiert werden.

Die Forschungsprojekte ROSE und INITIATIVE eHealth an der Hochschule Osnabrück sind Beispiele in denen Daten unterschiedlicher Teilprojekte gesammelt und in einer gemeinsame Forschungsdatenbank zusammengeführt werden sollen, um ein lernendes Gesundheitssystems in der Region Osnabrück zu realisieren [Hü16]. Dazu werden Primärdaten in unterschiedlicher Form erhoben (schriftliche Befragungen, Interviews) und mit Sekundärdaten (z. B. Qualitätsberichte der Krankenhäuser, demographische Daten der statistischen Ämter) zusammengeführt. Die Befragungsdaten werden je nach Teilprojekt einmalig oder in regelmäßigen Intervallen erfasst. Neue Forschungsideen führen dabei oft zu sich ändernden Items und damit zu sich ändernden Schnittstellen. Dennoch sollen die Schnittmengen der in allen Erhebungen gleichen Daten abgebildet werden, d.h. es sollen longitudinale Analysen und Quellenzusammenführung bei gleichem Erhebungszeitpunkt möglich sein. Dies setzt voraus, dass die Daten nicht isoliert abgelegt, sondern in einer zentralen Forschungsdatenbank zusammengeführt werden. Diese soll als eine integrierte Plattform zur Verwaltung, Analyse und Präsentation von Forschungsdaten dienen und unter Nutzung von Open Source Komponenten entwickelt, implementiert und kontinuierlich verbessert werden.

Mit diesem Artikel wird das grundlegende Systemdesign gezeigt und die Implementation des Datenmodells als erster Meilenstein fokussiert. Zur Erhebung der Anforderungen wurden Interviews mit Anwendern aus den Forschungsgruppen der Teilprojekte durchgeführt. Ein zentrales Anwendungsgebiet ist dabei die seit 2002 bundesweit und in den letzten Jahren auch international durchgeführte Befragung zum Digitalisierungsgrad in Krankenhäusern [Fo02]. Der Digitalisierungsgrad von Krankenhäusern unterliegt einem inkrementellen Wachstum, was zu einem Bedarf an longitudinalen Studien führt [Bu11]. Außerdem führt der kontinuierliche

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technische Fortschritt zu sich mit der Zeit ändernden und neuen Befragungsitems [Ag10]. Um die Auswirkungen dieses innovativen Prozesses auf Krankenhäuser und deren Umwelt für Praktiker, Politik und Patienten sichtbar zu machen, müssen die Befragungsdaten um Sekundärdaten (z. B. Qualitätsberichte der Krankenhäuser) in den jeweiligen Analyse ergänzt werden [Am09]. Für das Datenmodell ist daher zentral, dass es einerseits robust gegenüber Datenarten aus unterschiedlichen Datenquellen ist und deshalb über ein hohes Maß an Erweiterbarkeit verfügt. Dazu müssen auch semantische Änderungen (z.B. Änderung des Fragetextes bei Befragungsdaten) nicht nur kompatibel mit dem Datenmodell sein, sondern auch nachvollziehbar abgebildet werden können. Andererseits soll das Datenmodell verschiedene analytische Sichten auf die integrierten Daten gestatten und daher keine Form der Auswertung, z. B. nach Dimensionen und Fakten, vorschreiben. Außerdem sollen externe Informationen wie beispielsweise Qualitätsdaten oder andere frei verfügbare Daten integriert werden.

Es konnten insgesamt sechs wesentliche Anforderungen konkretisiert werden: (1.) Das Datenmodell soll beliebige Befragungsdatensätze unterschiedlicher Quellformate integrieren, ohne die Datenstrukturen anpassen zu müssen. (2.) Neue Umfrageschnittstellen sollen an das System angeschlossen werden können, ohne die bestehende Struktur des Datenmodells ändern zu müssen. (3.) Das Datenmodell soll sowohl in Bezug auf das Hinzufügen weiterer Merkmale, als auch hinsichtlich vereinzelter Merkmalsausprägungen skalieren. (4.) Zeitlich gesehen sollen Quer- und Längsschnittanalysen möglich sein. Dazu ist es essentiell, identische Teilnehmer und Items aufeinander abzubilden und die Veränderung von Merkmalsausprägungen zu historisieren. (5.) Das Datenmodell soll um zusätzliche Datenquellen erweiterbar sein, die Items oder Teilnehmer beschreiben, ohne die bestehende Struktur des Datenmodells ändern zu müssen. (6.) Das Datenmodell soll sich um die Datenstrukturen zentrieren und auswertungsunabhängig sein. Es soll insbesondere keine Kausalitäten oder gerichtete Zusammenhänge zwischen Merkmalen implizieren, sondern sich auf die reinen Datenrelationen beschränken.

Die Anforderungen implizieren, dass das Datenmodell in generischer Weise Befragungsdaten beschreiben kann, aber auch erweiterbar bezüglich unvorhergesehener Spezifika von Befragungsdaten oder weiteren Datenquellen ist, wie sie etwa durch neue Erhebungsinstrumente oder Sekundärdaten hinzukommen können. Außerdem beinhalten die Anforderungen, dass Items wiederholter Erhebungen, als solche auch verknüpft werden und die Änderungen explizit abgefragt werden können. Umgekehrt sollen ebenfalls befragungsübergreifend sämtliche Ausprägungen von Items für ausgewählte Merkmalsträger zusammengeführt werden. Dieses führt zu den diesem Beitrag zugrundeliegenden Forschungsfragen:

- FF1: Welches Datenmodell eignet sich als konzeptuelle Grundlage für die Umsetzung der genannten Anforderungen?
- FF2: Wie kann am Beispiel mehrjähriger und unterschiedlich strukturierter Umfragedaten ein vereinheitlichtes Datenmanagement implementiert werden?

In Kapitel 2 wird zunächst ein Überblick über unterschiedliche Datenmodelle gegeben und welche Vor- und Nachteile diese jeweils bieten. Anschließend wird in Kapitel 3 das entwickelte Konzept für die Forschungsdatenbank erläutert. Schließlich werden in Kapitel 4 die konkreten Implementierungen vorgestellt und abschließend in Kapitel 5 zusammenfassend betrachtet.

2 Stand der Forschung

Data Warehouse Systeme sind Informationssysteme, die regelmäßig anfallende Daten aus verschiedenen Quellen integrieren und die Daten organisieren, so dass unterschiedlicher Zustände der Informationsobjekte abgebildet werden und zeitliche Veränderungen abgerufen werden können [In05]. Ein Data Warehouse System umfasst neben der persistenten Datenhaltung sowohl Datenschnittstellen zu Quell- und Zielsystemen als auch Software zur Datenintegration und Monitoring sowie graphische Benutzerschnittstellen zur Datenanalyse [Ba13]. Für den vorliegenden Beitrag wird das zugrundeliegende Datenmodell fokussiert.

Klassische Datenmodelle aus dem Bereich der Wirtschaftsinformatik für Data-Warehouse-Systeme sind normalisierte Relationale Modelle und die Dimensionale Modellierung (Sternschema) [Ba13]. In der Medizinischen und der Gesundheitsinformatik hat sich parallel zu den klassischen Datenmodellen das Entity-Attribute-Value-Datenmodell entwickelt [Lö12]. Ein weiterer Modellierungsansatz, der in den letzten Jahren vermehrt für unterschiedlichste Geschäftsanwendungen angewendet wurde, ist das Data-Vault-Modell (DV) [Ch10]. In normalisierten Modellen werden Informationsobjekte, Attribute und die strukturellen Beziehungen explizit abgebildet. In dimensionalen Modellen werden Daten hingegen als Ereignisse (Fakten) und ereignisbeschreibende Dimensionen abgebildet. Normalisierte Modelle sichern die Konsistenz und referentielle

Integrität der Daten. Neue Datenquellen oder die Anpassung bestehender Daten führen jedoch zu aufwendigen strukturellen Änderungen [DN07]. Bei der dimensionalen Modellierung werden die Daten anforderungsgetrieben bereits für die Analyse als abhängige Variablen (Fakten) und unabhängige Variablen (Dimensionen) modelliert [KR13]. Dementsprechend führen neue Analyseanforderungen auch bei dimensionalen Modellen zu aufwendigen strukturellen Änderungen. Daten aus der Medizin und dem Gesundheitswesen stellen diese klassischen Datenmodelle häufig vor neue Herausforderungen, weil dort jedes Informationsobjekt viele Merkmale besitzt und fortlaufend neue hinzukommen können. EAV-Modelle spezifizieren Merkmale daher nicht in einem festgelegten strukturellen Schema, sondern zeilenweise auf Datensatzebene. Dadurch können heterogene Daten mit sich laufend ändernden Datenstrukturen persistiert werden. Dieses führt jedoch zu komplexen Abfragen [DN07]. Bei der DV-Modellierung werden Informationsobjekte, Attribute und Beziehungen voneinander getrennt modelliert. Dadurch können die Datenstrukturen bei neuen Analyseanforderungen erweitert und müssen nicht geändert werden [Bo16], [JSM14]. In der wissenschaftlichen Literatur wird die DV-Modellierung bislang wenig betrachtet.

Es gibt Ansätze die Datenmodelle miteinander zu kombinieren. Dazu wurde beispielsweise ein EAV-Modell in weiteren Architekturschichten eines Data Warehouses in ein (1) Sternschema überführt [Ya12] oder in eine (2) dimensionale Struktur eingebettet [WHM11], [Mu10]. In Ansatz (1) bleibt in der weiteren Architekturschicht das Problem der sich fortlaufend hinzukommender Merkmale und neuer struktureller Anforderungen bestehen. In Ansatz (2) werden EAV-Tabellen als Faktentabellen und Dimensionen als Attributsdimensionen modelliert. Dadurch wird zwar die Erweiterbarkeit des EAV-Modells bewahrt, jedoch ist die strukturelle Anpassung der Dimensionstabellen weiterhin eingeschränkt. Bisher gibt es keinen Ansatz, EAV-Modelle mit DV-Modellen zu verknüpfen, um für ein besseres Strukturieren der Daten ohne Verlust der Flexibilität des EAV-Ansatzes zu sorgen.

3 Konzept

Klassische Datenmodelle können die oben angeführten Anforderungen (1.), (2.), (3.) und (6.) eines Data Warehouses nicht hinlänglich bedienen. In dieser Arbeit sollen daher alle eingangs aufgestellten Anforderungen durch die Kombination des EAV-Ansatzes mit dem DV-Modell umgesetzt werden (FF1).

Unser Systemdesign umfasst zunächst eine 5-Schichten-Architektur, bestehend aus je einer Schicht für die Datenerfassung, der Datenhaltung, die Datenverarbeitung und die Datenpräsentation. Diese sind über eine fünfte Schicht zur Datenintegration miteinander verbunden (vgl. Abb. 1). Die Datenerfassungsschicht beschreibt alle Instrumente, aus denen die relevanten Daten stammen. Die Datenhaltung wird durch ein Data Warehouse zur Datenkonsolidierung und Speicherung beschrieben und besteht aus drei weiteren Schichten: In der Quellschicht wird zunächst jede der von der Datenerfassungsschicht bereitgestellten Datenquellen als relationale Datenbanktabelle gespiegelt und zur weiteren Verarbeitung gespeichert. Die Primärdaten aus verschiedenen Umfragen und Sekundärdaten (z. B. Qualitätsberichte, Krankenhausverzeichnis, klinische Daten) werden in der Kernschicht in eine konsolidierte Form transformiert. Data Marts bieten in der Analyseschicht optimierte Ansichten mit automatisch aggregierten Daten für vordefinierte Analysen. Um komplexere Berechnungen durchzuführen, werden die Daten in weitere Werkzeuge der Datenverarbeitungsschicht geladen und relevante Ergebnisse in weiteren Data Marts gespeichert. Der Austausch der Daten erfolgt zentral über die Datenintegrationsschicht. In der Präsentationsschicht werden die Daten für standardisierte regelmäßige Berichte oder für weitere Untersuchungen angezeigt.

In diesem Artikel soll auf die Datenhaltung der Kernschicht fokussiert werden. Zur Repräsentation der Umfragedaten wird die Datenstruktur in die Informationsobjekte Merkmalsträger, Merkmal und Merkmalsausprägung unterteilt. Nach den eingangs spezifizierten Anforderungen sollen Merkmalsträger, neben den Umfragedaten, mit Daten aus weiteren Datenquellen (z.B. Krankenhausverzeichnis, Qualitätsberichte) verknüpft werden. Außerdem sollen Merkmale und Merkmalsausprägungen durch Metadaten näher beschrieben werden. Daher werden in diesem Konzept, im Gegensatz zum EAV-Schema, die Informationsobjekte nicht als Entität, Attribut und Wert, sondern jeweils als eigenständige Entitäten modelliert. Die Forschungsdaten werden somit in Entitäten für Merkmalsträger (z. B. Befragungsitems, Klinikstandorte), Gruppen von Merkmalen (z. B. thematische Itemblöcke, Diagnosesysteme) und Ausprägungen (z. B. Antwortoptionen, Fallzahlen) organisiert.

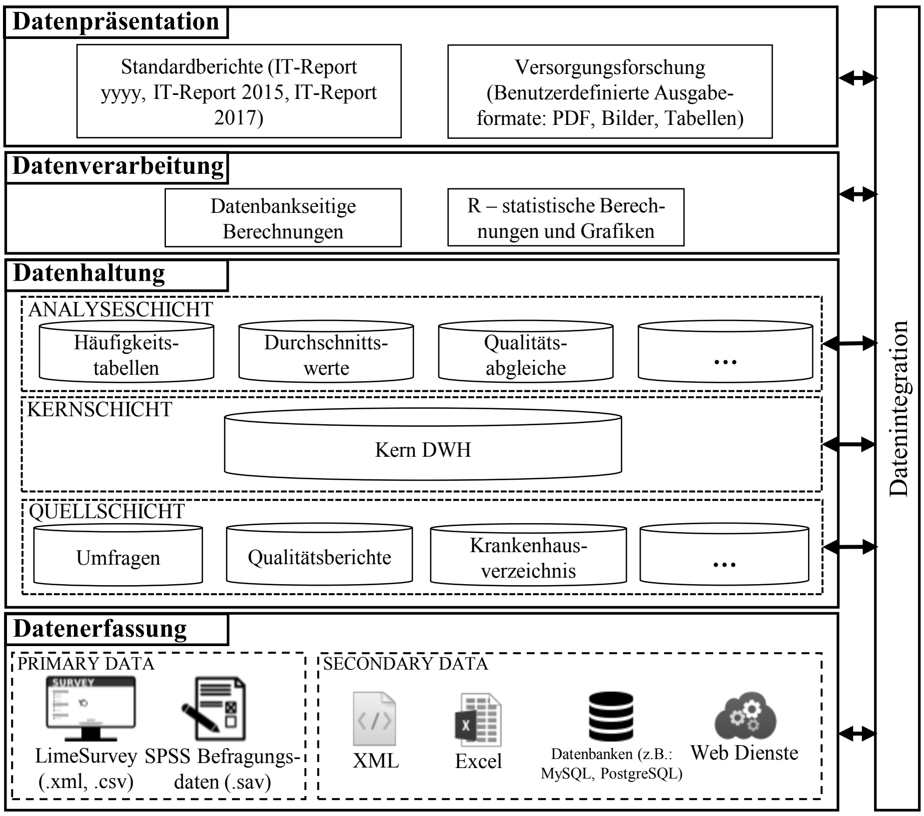

Abb. 1: 5-Schichten-Architektur - Systemdesign

Für jede Entität wird nach der DV-Modellierung eine *Hub*-Tabelle erstellt. Jeder *Hub* beinhaltet sowohl den natürlichen Schlüssel der Entität als auch einen generierten technischen Schlüssel [LO16]. Die technischen Schlüssel werden in *Link*-Tabellen als Referenz genutzt, um die *Hubs* bzw. Entitäten miteinander zu verknüpfen. Es ergibt sich also an Stelle der Entität-Attribut-Wert-Tabelle ein ternärer Link "Merkmalsträger-Merkmal-Ausprägung", der auf die entsprechenden Entitätsschlüssel verweist. Die unmittelbare Abhängigkeit zwischen Ausprägungen und Merkmalen, die sich beispielsweise aus der Beziehung zwischen Fragebogenitems und Antwortvorgaben ergibt, wird ebenfalls als *Link* "Merkmal-Ausprägung" modelliert. Das Datenschema bildet ab, welche Entitäten miteinander in Beziehung stehen. *Hubs* und *Links* sind nach der Data Vault-Spezifikation [LO16] zeitinvariant und beschreiben daher lediglich, welche Entitätsinstanzen in der Historie gemeinsam aufgetreten sind. In der DV-Modellierung werden alle zeitvarianten Daten (z.B. Entitätsattribute) innerhalb sogenannter *Satellites* modelliert. Die Historisierung der Datensätze erfolgt über Zeitstempel, wobei Datensätze weder überschrieben noch gelöscht werden. Die Teilnahme an Forschungsumfragen ist anonymisiert bzw. pseudonymisiert, sodass der natürliche Schlüssel eines Merkmalsträgers abhängig von der jeweiligen Befragungsrunde ist. Der Merkmalsträger ist daher als "Teilnahme" und nicht als "Teilnehmer" zu verstehen. Die longitudinale Verknüpfung von Teilnahmen zu Merkmalsträger, deren zeitlich variierende Ausprägungen analysiert werden sollen, erfolgt durch einen weiteren *Link* "Teilnahme-Merkmalsträger". Dadurch werden Teilnahmen mit den dazugehörigen Merkmalsträgern identifiziert. Auf den *Hub* "Merkmalsträger" kann nun mit beliebigen zusätzlichen Entitäten über *Links* und die *Links* beschreibenden *Satellites* referenziert werden. *Hubs* sind somit passive Kataloge, sodass das Schema für die Befragungsdaten nicht modifiziert werden muss.

4 Implementierung

Das Systemdesign wurde vollständig mit Open Source Komponenten umgesetzt. Das System selbst wurde auf einem Ubuntu Server 16.04 mit PostgreSQL 9.6 implementiert. Die Datenintegration zwischen den einzelnen Schichten wurde mit Pentaho Data Integration 7 implementiert. Die Statistiksoftware R 3.3.2 wurde für erste longitudinale Berechnungen und Visualisierungen mit ggplot2 2.2.1 eingesetzt [WC16]. Primärdaten wurden aus LimeSurvey 2.54.3 und aus archivierten Umfragedatensätzen der Statistiksoftware SPSS von IBM aus vorherigen Jahren extrahiert. Sekundärdaten wurden aus den Krankenhaus-Qualitätsberichten des Gemeinsamen Bundesausschuss (G-BA) und dem deutschen Krankenhausverzeichnis entnommen.

SPSS bietet drei Komponenten, mit denen sowohl die Fragebogenstruktur, als auch die Umfrageergebnisse abgebildet werden können: (1) Das Datenblatt, das die Umfrageergebnisse enthält, besteht aus dem Teilnehmer

(Zeile), dem Item bzw. der Variable (Spalte) und der gewählten Antwortoptionen (Zelle). (2) Die Spezifikation der Items liefert die Item-Label, Skalenniveau und Formatierungsattribute. (3) Die Spezifikation der Itemausprägungen bezeichnet Label und Kodierungen. Diese drei Komponenten können als separate CSV-Dateien exportiert werden. Das Datenblatt (1) wird durch die Metadaten aus (2) und (3) näher beschrieben.

LimeSurvey bietet einen Export der Fragebogenstruktur und der Umfrageergebnisse. Das Datenblatt für die Umfrageergebnisse ist strukturell identisch mit dem SPSS-Datenblatt und wird als CSV-Datei exportiert. Die Fragebogenstruktur wird als XML-Dokument exportiert. In diesem sind Fragetexte in Kombination mit Antworttexten zu Items instanziiert, sodass keine 1:1 Beziehung zwischen Fragetext und Item besteht. Eine Multiple-Choice-Frage mit vier Antwortoptionen korrespondiert beispielsweise mit fünf Item-Spalten im LimeSurvey-Datenblatt. Daraus folgt, dass die exportierte Fragenbogenstruktur zunächst in die semantische Struktur von Merkmalsträger, Merkmal und Ausprägung transformiert werden musste, damit Metadaten für das LimeSurvey-Datenblatt extrahiert werden können.

Gemäß der Data-Vault-Spezifikation wurden *Hubs*, *Links* und *Satellites* eins-zu-eins als relationale Tabellen erstellt (vgl. Abb. 2). Primär- und Fremdschlüssel-Beziehungen wurden als Constraints in PostgreSQL angelegt. Der MD5-Hashing-Algorithmus wurde eingesetzt, um auf Basis des natürlichen Schlüssels (z.B. Fragencode, Antwortoption, Qualitätskennziffer) den technischen Schlüssel der Entitäten zu erzeugen. Die Datensätze werden um die Attribute *load_dts* und *rcd_src* ergänzt, welche das Erhebungsdatum der Befragung zur Historisierung der unterschiedlichen Umfragen und den vollständigen Dateipfad der jeweiligen Quelldatei enthalten. Alle Fragen werden, unabhängig vom Quellsystem, im Hub *h_item* konsolidiert. Dieser Hub hat insgesamt drei *Satellites*. Der generische *Satellite s_item* enthält die Attribute, die für Merkmale universell sind. Zusätzlich gibt es für die beiden Quellsysteme SPSS und LimeSurvey je einen *Satellite*, der systemspezifische Merkmalsattribute erfasst. Als Beispiel für die Einbeziehung von Sekundärdaten, können die frei zugänglichen Qualitätsberichte (XML-Dateien) deutscher Krankenhäuser angeführt werden. Diese können mit demographischen Daten aus dem Krankenhausverzeichnis verknüpft werden. Wie bereits bei den Befragungsdaten wurden auch hier gemäß der Data Vault-Spezifikation *Hubs* für die Entitäten, *Links* für die Beziehungen und *Satellites* für zeitabhängige und deskriptive Attribute erstellt. Die zentrale Beziehung ergibt sich hier zwischen den Entitäten Klinikstandort, Auswertungseinheit, Leistungsbereich und Qualitätsindikator.

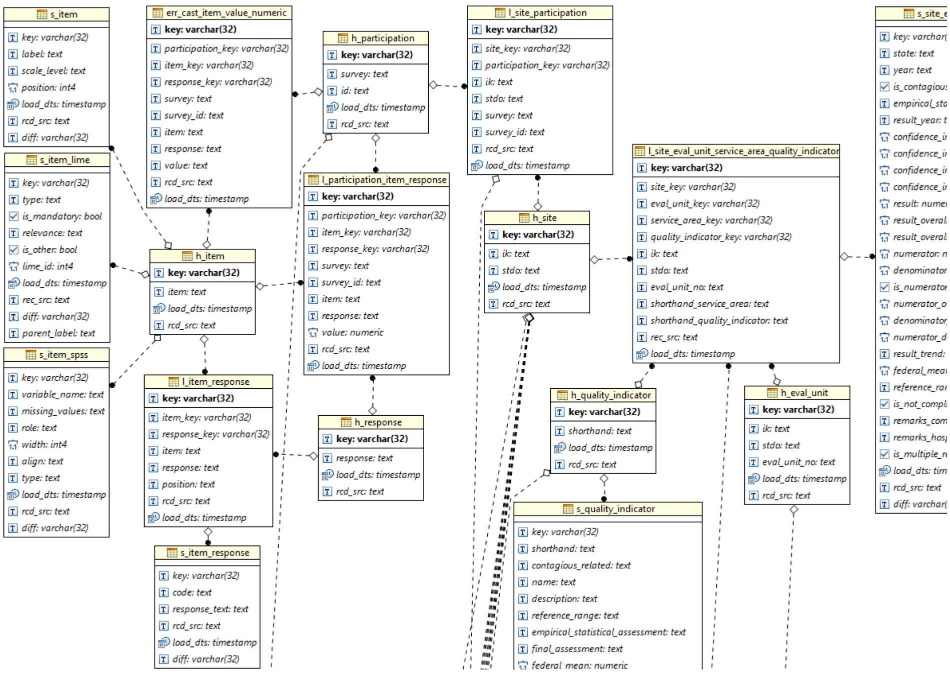

Abb. 2: Ausschnitt des Datenmodells zur Abbildung der Befragungsdaten und Qualitätsindikatoren

Das diesem Datenmodell zugrundeliegende Kern DWH (vgl. Abb. 1) enthält Daten von Befragungen aus den Jahren 2011, 2013, 2015 und 2017 (2011: 339 Teilnahmen mit 203

Items, 2013: 259 Teilnahmen mit 521 Items, 2017: 194 Teilnahmen mit 226 Items). Für die Qualitätsberichte der Jahre 2011 bis 2014 liegen insgesamt 733.000 Datenwerte für 381 Qualitätsindikatoren vor, verteilt auf insgesamt knapp 20.000 Auswertungseinheiten und 39 Leistungsbereiche.

5 Zusammenfassung, Fazit und Ausblick

Die Herausforderungen an unterschiedliche Datenmodelle für ein umfassendes Datenmanagement wurden in diesem Beitrag kritisch betrachtet. Die DV-Modellierung ist zwischen dem EAV-Ansatz und dem Sternschema einzuordnen. Dem EAV-Ansatz liegt ein generisches Datenmodell zugrunde, was jedoch zu komplexen Abfragen führt. Ferner ist das EAV-Modell sehr flexibel, kann jedoch keine semantischen Änderungen von Daten verfolgen. Sobald Attribute von Entitäten geändert werden müssen oder die Semantik von Attributen geändert wird, muss eine Erweiterung des EAV-Modells stattfinden. Das Sternschema hat hingegen festgelegte Dimensionen und Faktenwerte, wodurch Abfragen einfacher sind, jedoch die Analyseoptionen bereits festgelegt sind. Mit der DV-Modellierung steht es frei, beispielsweise die Qualitätsindikatoren als einen *Hub* zu modellieren oder unterschiedliche Qualitätsindikatoren über mehrerer *Hubs* abzubilden. Die DV-Modellierung ermöglicht umfassende Historisierungen der Datenänderungen, jedoch steigt mit der Flexibilität auch die Komplexität des Systems, sodass diese Designentscheidung konkret spezifiziert werden muss, um einem zu hohen Entwicklungsaufwand ohne zugrundeliegender Anforderungen entgegenzuwirken.

In diesem Beitrag wurde daher das EAV mit dem DV-Modell zum Persistieren semantisch heterogener Befragungsdaten (FF2) kombiniert. Das vorgestellte Modell liefert somit eine integrierte Sicht auf Datensätze unterschiedlicher Quellen, wie am Beispiel von SPSS- und LimeSurvey-Datensätzen gezeigt wurde und historisiert vollständig Befragungs- und Metadaten. Dadurch kann beispielsweise eine veränderte Semantik durch abweichende Wortlaute eines Items nachvollzogen werden und die Item-Gruppen, die sich in natürlicher Weise aus der Fragebogenstruktur aus LimeSurvey ergeben, für die zugeordneten SPSS-Items übernommen werden. Das Datenmodell kann durch neue Entitäten und Beziehungen erweitert werden. Neue Attribute oder Umfragesysteme werden durch zusätzliche *Satellites*, neue Teilnehmertypen durch neue *Links* zur zentralen Relation "Teilnahme-Merkmal-Ausprägung" implementiert.

Mit dem DV-Modell konnte der EAV-Ansatz, bestehend aus Entitäten, Attributen und Werten, generalisierbar erweitert werden, sodass alle Informationsobjekte als eigenständige Entitäten modelliert wurden. Durch diese, im Vergleich zum EAV-Ansatz, lose Kopplung der Beziehungen können unterschiedliche Informationsobjekte zusammen integriert und historisiert werden. Jede Entität wird als *Hub* mit mehreren *Links* und *Satellites* implementiert. Limitationen ergeben sich durch Änderungen von Attributspalten eines Satelliten zu eigenständigen *Hubs*, weil diese Transformationen sehr aufwändig sind. Daten, welche als *Hubs* implementiert werden sollen, müssen daher im Designprozess frühzeitig definiert werden. Entitäten mit heterogenen und inkonsistenten Daten sollten daher grundsätzlich als *Hubs* modelliert werden. Das resultierende Modell ist im Ergebnis soweit generalisierbar, dass es sich auf Messergebnisse aller Art allgemein übertragen ließe, da die Relation Merkmalsträger-Merkmal-Ausprägung auf fast alle statistisch auszuwertenden Daten anwendbar ist.

Die Datenhaltung ist der erste Meilenstein in Richtung einer Gesamtarchitektur für ein umfassendes Forschungsdatenmanagement. Zukünftige Arbeiten liegen in der Vereinfachung von standardisierten, regelmäßigen Abfragen durch vordefinierte Prozesse. Dadurch soll mittelfristig der Zeitraum zwischen Erhebung der Daten und Bereitstellung der Informationen für wissenschaftliche Analysen und die Präsentation der Ergebnisse für Praxis und Politik minimiert werden. Weitere zukünftige Schritte sind die Entwicklung von Web-Front-Ends für die unterschiedlichen Teilprojekte (klinische Entscheidungsunterstützung [Hü16], Best Practices im Rahmen eines Benchmarkings zur Digitalisierung deutscher Krankenhäuser [Th14]), mit denen wissenschaftliche Ergebnisse in einer nutzerorientierten Sichtweise in die Praxis überführt werden können.

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Beitrag 12: Antecedents of CIOs' Innovation Capability in Hospitals: Results of an Empirical Study.

Titel	Antecedents of CIOs' Innovation Capability in Hospitals: Results of an Empirical Study
Autoren	Jan-David Liebe Moritz Esdar Johannes Thye Ursula Hübner
Publikationsorgan	Studies in Health Technology and Informatics
Ranking	VHB JQ3: - WKWI: - IF: - AQ: 50%-70%
Status	Angenommen (in Veröffentlichung)
Bibliographische Information	Liebe, J.-D., Esdar, M., Thye, J., und Hübner, U. (2017) Antecedents of CIOs' Innovation Capability in Hospitals: Results of an Empirical Study, in: Rörig, R., Timmer A. (Hrsg.): 62. GMDS-Jahrestagung, Mit Visionen Brücken bauen (GMDS 2017), Studies in Health Technology and Informatics, in Veröffentlichung, Oldenburg, Amsterdam, S. 1-5.
Link	-/-
Copyright	Studies in Health Technology and Informatics

Tabelle 13. Überblick Beitrag 12

Antecedents of CIOs' Innovation Capability in Hospitals: Results of an Empirical Study

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Abstract. CIOs' innovation capability is regarded as a precondition of successful HIT adoption in hospitals. Based on the data of 142 CIOs, this study aimed at identifying antecedents of perceived innovation capability. Eight features describing the status quo of the hospitals IT management (e.g. use of IT governance frameworks), four features of hospital structure (e.g. functional diversification) and four CIO characteristics (e.g. period of employment) were tested as potential antecedents in an exploratory stepwise regression approach. Perceived innovation capability in its entirety and its three sub-dimensions served as criterion. The results show that CIOs' perceived innovation capability could be explained significantly (R^2=0.34) and exclusively by facts that described the degree of formalism and structure of IT management in a hospital, e.g. intensive and formalized strategic communication, the existence of an IT strategy and the use of IT governance frameworks. Breaking down innovation capability into its constituents revealed that "innovative organizational culture" contributed to a large extent (R^2=0.26) to the overall result sharing several predictors. In contrast, "intrapreneurial personality" (R^2=0.11) and "openness towards users" (R^2=0.18) could be predicted less well. These results hint at the relationship between working in a well-structured, formalized and strategy oriented environment and the overall feeling of being capable to promote IT innovation.

Keywords. CIO, innovation capability, intrapreneurship, strategic cooperation

1. Introduction

Health information technology (HIT) innovations are considered to be an intrinsic component of hospitals success [1]. This said, HIT innovations are less about specific IT applications, but about building "digital options" through complex integrated and multifunctional systems [1, 2]. In expert organizations like hospitals, this goal can only be achieved by making the right IT investments and, at the same time, by considering the complex network of social, organizational and technical aspects that surround successful HIT implementation [3]. Chief information officers (CIOs) stand at the heart of corresponding management activities [4]. Their perceived ability to initialize, implement and institutionalize new and suitable HIT solution can be defined as *innovation capability* [5], a construct composed of latent personal and organizational characteristics, i.e. of an *innovative organizational culture* and of the CIOs'

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intrapreneurial personality and *openness towards users* [6]. Innovative organizational culture describes a working environment that nurtures unorthodox thinking and its application and which is based on shared values, basic underlying assumptions and observable artifacts [7, 8]. With regard to HIT innovations, innovative organizational culture can be characterized by shared visions about the future role of HIT, by a supportive hospital board (HB) and by a certain degree of flexibility in organizational structures, processes and work routines [3, 6]. Intrapreneurial personalities were originally characterized as "(..) dreamers who do. Those who take hands-on responsibility for creating innovation of any kind, within a business" [9]. Intrapreneurial hospital CIOs' can be characterized as being risk-affine and pro-active in regard to new HIT solutions [6, 10]. They are inclined to compensate a lack of decision-making powers with entrepreneurial thinking and actions [6, 10]. Openness towards users can be defined by a strong orientation on clinicians' needs, the willingness to cooperate with users in IT project and by the awareness of social standings and professional autonomy [3, 5, 6].

In a previous study, we reported about developing an *innovation capability* score for hospital CIOs [6]. Based on this, it seems to be promising for researchers and practitioners (i.e. hospital managers) to explore antecedents of CIOs' innovation capability. In HIT adoption research, several approaches to explain the origin of innovations theoretically and empirically can be found [11,12]. On the one hand, various studies focus on the *status quo of IT management*, which surrounds HIT implementation, e.g. the sophistication of strategic cooperation between CIO and HB, the use of IT governance frameworks or the existence of an IT strategy [10]. On the other hand, there are several studies that regard HIT innovations to be influenced by *structural hospital characteristics* like size, functional differentiation, teaching status or ownership [11]. Finally there is a large body of research on *individual characteristics* to explain innovativeness (e.g. qualification in terms of working experience or degree) [12]. Considering these diverse research streams, this study intends to explore antecedents of the CIOs' innovation capability in hospitals.

2. Methods

The study is based on data captured in a nationwide survey among 1284 CIOs in German hospitals between February and April of 2016 [13]. Starting from this data we developed a composite-score to measure the perceived *innovation capability* of CIOs. The score was found to be reliable and valid and consited of three subdimensions: *innovative organizational culture*, *intrapreneurial personality* and *openness towards users*. The development of the scores was published in Esdar et al. 2017 [6]. To expolore the antecedents of the CIOs' innovation capability we chose to perform four stepwise regression models. The composite-score and its three sub-dimensions served as dependent variable. As independent variables we used sixteen attributes which decribe the status quo of IT management as well as the structure of the hospital and the individual characteristics of the CIO. The *status quo of IT management* was operationalized by eight items: number of frequently communicated strategic information between CIO and HB as a measure of communication intensity, circumstances in which CIO and HB usually communicate (e.g. coffee breaks vs. official meetings) as a measure of formalization, use of a dashboard application to visualize strategic information (management cockpit), use of IT governance frameworks, existence of an IT strategy, membership of a nurse and/or a physician in the HB and status of a reference hospital as a measure for a formalized cooperation with IT vendors. *Structural hospital demographics* were measured by four items: number of in-patient beds as a measure of size, number of clinical units as a measure of functional diversification, teaching status and private ownership. *Individual characteristics* of the CIO were measured by four items: work experience (in years), period of employment (in years), clinical background of the CIO (e.g. nursing) and university degree. We tested for normal distribution and homoscedasticity of the residuals as well as for multicollinearity (by calculating the variance inflation factor (VIF)). Data were analyzed with SPSS 24®.

3. Results

Data from 142 CIOs (response rate 11.1%) were included in the analysis after the original data set (n=176 [13]) was adjusted for missing data in terms of consistency over all items. CIOs in the final sample were responsible for 17.6% of the German hospitals (n=344) [14]. Table 1 and Table 2 present descriptive statistics of all items that were included in the regression models.

Table 1. Descriptive statistics of binary items (n=142)

Item	Yes	No
Formalization (CIO and HB rather communicate in formal meetings)	57.0%	43.0%
CIO uses a management cockpit to visualize strategic information	14.8%	85,2%
IT governance frameworks (e.g. COBIT, ITIL) are used	35.2%	64.8%
An IT strategy exits	76.8%	23.2%
Formalized cooperation with IT vendors (status of a reference hospital)	42.3%	57.7%
A nurse is member of the HB	59.9%	40.1%
A physician is member of the HB	71.8%	28.2%
Hospital is a teaching hospital	56.3%	43.7%
Hospital is privately owned	12.7%	87.3%

Table 2. Descriptive statistics of metric items (n=142, [1]value range 1 to 100)

Item	Mean	SD	Min.	Max.
Communication intensity (freq. communicated information)	2.6	0.5	1,0	3.9
Functional diversification (number of clinical units)	9.2	8.0	1.0	45.0
Size (number of beds)	414	321	45	1563
CIOs' work experience (years)	14.0	8.3	0.0	35.0
CIOs' period of employment (years)	11.7	7.8	0.0	32,0
Innovation capability[1]	56.0	12.4	28.2	87.9
Innovative organizational culture[1]	43.8	21.1	0.0	100.0
Intrapreneurial personality[1]	42.3	15.0	36.2	100.0
Openness towards users[1]	74.7	14.1	0.0	86.7

The stepwise inclusion of the 16 predictors resulted in four significant regression models. Five predictors, assigned to *status quo of IT management*, significantly explained 34.4% variance of *innovation capability*. Four of those predictors significantly explained 25.9% of *innovative organizational culture*. *Openness towards users* was significantly explained by three and *intrapreneurial personality* by two of the 16 predictors (Table 3). Residuals were normally distributed and showed no signs of heteroscedasticity, neither did the calculated VIF indicate multicollinearity.

Table 3. Stepwise regression models (n=142)

	Innovation capability		Innovative org. culture		Intrapreneurial personality		Openness toward users	
	Cor. R^2= .34		Cor. R^2=.26		Cor. R^2=.11		Cor. R^2=.18	
	Beta	VIF	Beta	VIF	Beta	VIF	Beta	VIF
Status quo of IT management								
Communication intensity	.229	1.235	.273	1.219	-	-	-	-
Formalization	.311	1.130	.238	1.102	.255	1.027	-	-
Use of mgmt. cockpit	.148	1.108	.151	1.078	-	-	-	-
Use of IT governance	.187	1.079	-	-	.200	1.027	-	-
Existence of IT strategy	-	-	.148	1.084	-	-	-	-
Reference hospital	-	-	-	-	-	-	-	-
Physician is HB member	.118	1.034	-	-	-	-	.150	1.013
Nurse is HB member	-	-	-	-	-	-	-	-
Structural hospital demographics								
No. of beds	-	-	-	-	-	-	-	-
No. of clinical units	-	-	-	-	-	-	.189	1.147
Teaching hospital	-	-	-	-	-	-	-	-
Private ownership	-	-	-	-	-	-	-	-
Individual characteristics of the CIO								
Professional activity	-	-	-	-	-	-	-	-
Period of employment	-	-	-	-	-	-	-	-
University degree	-	-	-	-	-	-	.194	1.059
Clinical background	-	-	-	-	-	-	-	-

4. Discussion

Keeping in mind that *innovation capability* is a self-rated measure of the CIOs' ability to foster successful adoption processes [6], the results should be interpreted against the background of the initiation, implementation and institutionalization of HIT innovations. The main finding of this study is that CIOs estimate their innovation capability to be comparatively high if they maintain a sophisticated strategic cooperation with the hospital board. In hospitals, as in other organizations, technological innovations require the redirection of resources that would otherwise be allocated to non-IT related strategic objectives [5]. In this context it can be assumed that an intense and formal exchange of strategic information in association with the use of IT based management cockpits, supports the lobbying in favor of HIT initiatives. A sophisticated strategic cooperation might furthermore lead to optimal trade-offs between clinical and technical requirements [3, 10]. With regard to initial HIT investments, this may increase the CIOs' decision-making reliability and in turn the perceived innovation capability. This assumption is supported by the fact that CIOs perceive their innovation capability to be higher if a physician is part of the hospital board. Working together on establishing strategic IT initiatives might provide opportunities to educate each other about technical and clinical requirements [10]. In addition, clinicians in top management teams might act as "boundary spanners" to champion IT initiatives on the frontline level [3]. The certainty to be backed by clinical champions may furthermore facilitate the perceived capability to implement and institutionalize new HIT in clinical practice [5]. The ability to refer to an overriding IT strategy and IT governance frameworks could have similar effects on certainty in actions [6]. In contrast to former studies, which found structural hospital characteristics to determine HIT adoption rates [11], these findings cannot be applied to the innovation capability. This might be particularly promising for smaller hospitals, as the CIOs' perceived innovation capability seems to be rather a function of proper management conditions than of size or slack resources. This study is limited with regard to the response rate of 11.1% that might have caused a non-response bias in our sample. The results can therefore require further validation. Future research approaches could peruse additional predictors for *intrapreneurial personality* and *openness towards users* (e.g. the "big five" personality traits [12]) to better explain the perceived *innovation capability* as a whole.

5. Conclusion

This study is the first step towards a deeper understanding of CIOs' perceived innovation capability in hospitals. These insights help paving the way for an innovation culture in healthcare organizations.

6. Conflict of Interest

The authors state that they have no conflict of interests.

7. Acknowledgement

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Beitrag 13: Implementing a Data Management Platform for Longitudinal Health Research

Titel	Implementing a Data Management Platform for Longitudinal Health Research
Autoren	Jan-Patrick Weiß Ursula Hübner Jens Rauch Frank Teuteberg Moritz Esdar Jan-David Liebe
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Link	-/-
Copyright	Studies in Health Technology and Informatics

Tabelle 14. Überblick Beitrag 13

Implementing a data management platform for longitudinal health research

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Abstract. Health IT adoption research is rooted in Rogers' Diffusion of Innovation theory, which is based on longitudinal analyses. However, many studies in this field use cross-sectional designs. The aim of this study therefore was to design and implement a system to (i) consolidate survey data sets originating from different years (ii) integrate additional secondary data and (iii) query and statistically analyse these longitudinal data. Our system design comprises a 5-tier-architecture that embraces tiers for data capture, data representation, logics, presentation and integration. In order to historicize data properly and to separate data storage from data analytics a data vault schema was implemented. This approach allows the flexible integration of heterogeneous data sets and the selection of comparable items. Data analysis is prepared by compiling data in data marts and performed by R and related tools. IT Report Healthcare data from 2011, 2013 and 2017 could be loaded, analysed and combined with secondary longitudinal data.

Keywords. Survey data, longitudinal analyses, health IT adoption research

1. Introduction

Health IT adoption research is rooted in the work about the adoption and diffusion of innovation and draws on Rogers' Diffusion of Innovation (DOI) theory [1]. Health IT adoption studies often make use of surveying techniques to obtain the necessary information about IT adoption rates from samples of healthcare organisations and hereby, design their work as cross-sectional studies [2]. However, cross-sectional studies are only snapshots in time and therefore not suitable to study trends as the DOI theory requests. At the same time, longitudinal studies, which are more appropriate to answer these questions, demand more resources and are therefore underrepresented in the health IT adoption research [2,3]. IT Report Healthcare is a regularly conducted survey with a focus on measuring IT adoption in Germany, but also in Austria [4], the Netherlands and Switzerland that was developed in accordance with the OECD eHealth benchmark. IT Report Healthcare surveys like most other repetitive surveys, which capture information in a highly agile environment, face the same kind of issues: 1) new IT developments, 2) changing context, e.g. regulations, 3) changes of the statistical unit, e.g. merging of organisations, 4) availability of new data sources, 5) new research

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questions that are evolving from previous research findings. Thus, there is the need to encapsulate data from each point of time, to easily identify comparable items and to link only these data across time. It is the overall goal of the project to develop, implement and continuously improve an integrated platform for the management, analysis and visualisation of research data in IT adoption studies, but also in health services research. This part of the project focusses on the overall architecture and data management for longitudinal research. The aim of this study therefore was to design and implement a system built on open source components to (i) consolidate different items of one survey which was conducted in different years into one database, (ii) integrate additional secondary data sources and (iii) query and statistically analyse data over multiple years for longitudinal analyses.

2. State of the art

Data warehouse systems face the challenge of integrating several isolated information repositories into one single logical repository [5]. A literature and internet search, which was performed prior to the developments, resulted in no publications of a system that fulfilled the requirements as stated above. There were a few approaches to design and implement data warehouse systems for using survey-based data [6,7]. These approaches have a fixed concept in which the survey file formats, the survey structure and the user requirements stay the same and therefore are not flexible enough for iterative and agile research processes. IT adoption studies [8] often do not refer to any issues of data management but focus on data analytics primarily.

3. Concept

In order to meet these requirements, a hybrid approach for designing and implementing the system was chosen [9]. We combined a supply driven approach [5], in which we identified and analysed the data available, with a demand driven approach [10], in which we determined the requested information from users according to previous IT adoptions studies [11,12].

Our system design comprises a 5-tier-architecture that embraces a *data capture tier*, a *data tier*, a *logic tier* and a *presentation tier* (Fig. 1). They are connected via a fifth tier, the *data integration bus*. The *data capture tier* describes instruments from which the relevant data originates. The *data tier* is represented by a data warehouse for data consolidation and storage consisting of three layers: in the *source layer,* each of the data sources provided by the *data capture tier* is mirrored as a relational database table to ensure compliance with the defined data schema and data constraints. All extraction, transformation and loading (ETL) processes are implemented and executed through the *data integration bus*.

Primary data from different survey datasets and secondary data (e.g. hospital quality reports) are loaded into a consolidated form within the *core layer*. The core layer within the data tier constitutes the centre of data management and lays the foundation for flexible and longitudinal analyses. This is achieved via a schema that is based on the data vault model [13]. This schema is uncoupled from the model of the source layer to ensure flexibility. The data vault schema consists of three types of tables (hub, link, satellite). A hub represents a real-world or abstract object (e.g. survey item, site, quality indicator), which can be uniquely identified by its natural key. Each hub object receives a technical primary key and load timestamp for historicizing within the ETL process.

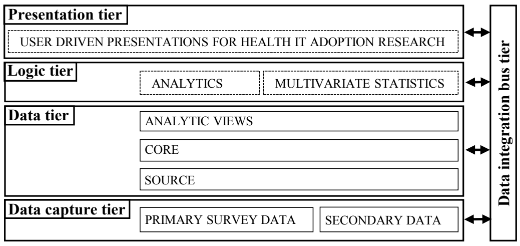

Figure 1. Overview of the system architecture

Links model the relationships between hubs (e.g. item – response, survey – site, site – response – quality indicator). A satellite contains attributes of one hub or one link. To historicize multiple temporal versions of attribute values its primary key is the foreign key of one hub/link with a timestamp. By separating natural keys (e.g. item codes, site ID) and the relationships between them from their attributes, a data schema is created that can, in comparison to the classical relational model [14], historicize various objects from different years and is able to combine these various objects in a flexible way, and to provide data for different, frequently changing query requirements.

Data marts, which constitute the analytics view layer in the data tier, provide optimised views with automatic aggregated data for predefined analyses. To perform more complex calculations, the data is loaded into further tools of the *logic tier* and the relevant results are stored back in additional data marts. This exchange service is represented via the *data integration bus*. In the *presentation tier* the data is displayed for standardised regular reports or for further research.

In contrast to other approaches, this concept does not focus on the integration of some specific types of data for certain use cases (e.g. clinical data [15], patient data [16]) but rather aims at the scalability through the data vault model approach for persistent, historicized storage of multiple surveys from different years.

4. Implementations

Pentaho Data Integration 7 served as the central *data integration bus* for all ETL jobs. Primary survey data were extracted from LimeSurvey 2.54.3 or legacy SPSS survey files from previous years. Secondary data was extracted from publicly available data sources (hospital quality reports, demographic hospital data). All data sources were loaded into relational database tables into the source layer (PostgreSQL 9.6 on Ubuntu Server 16.04). Then the data sources were transformed to one unified, consolidated, physical data vault schema (Fig. 2).

The data warehouse contains surveys of IT Report Healthcare from 2011, 2013 and 2017 (2011: 339 datasets, 203 items: 2013: 259 datasets, 521 items; 2017: 283 datasets, 226 items), historical demographic data of German hospitals from 2003 to 2014 (2883 datasets, 63 attributes) and hospital quality reports from 2012 to 2014 (381 quality indicators). In the design process, synonymously named items are mapped onto one item entity and stored in the hub *h_item*. Descriptive properties from the data sources, from which these items originated, are historicized in the satellites. Data marts were created to provide aggregated data e.g. denormalised demographic data of survey respondents or item frequency tables for longitudinal analysis. Data marts were accessed by the statistical software R 3.3.2 for data analysis and visualisation. Same survey items over the years 2011, 2013 and 2017 are provided by one data mart as frequency tables and were then further processed and visualised in R using the package *ggplot2 2.2.1* [17] (Fig. 3).

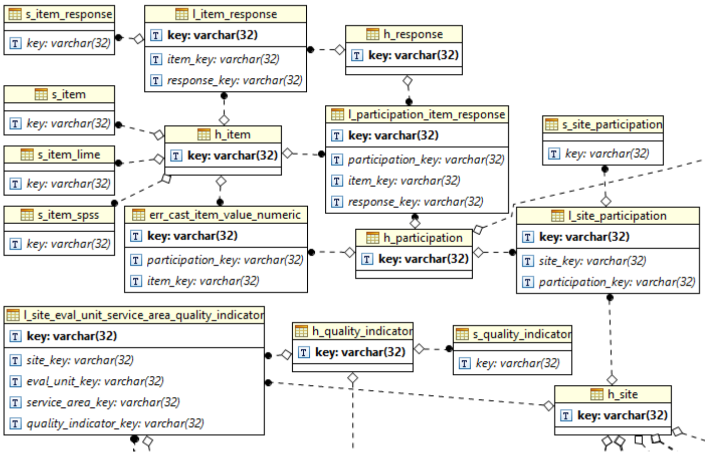

Figure 2. Excerpt of the deployed data vault model centered on the survey structure

5. Lessons learned

The proposed system for collecting, processing, storing and analysing data is composed of separate components, which are connected by ETL jobs. Each component can be replaced without affecting the rest of the system – except for the need of designing new ETL jobs. All tools used are open source and freely accessible. All relevant datasets could be loaded into the source layer. Using the proposed data vault model changes in the structure of the data source will lead to no changes in the structure of the model. Existing data can thus be easily extended by adding additional satellites, hubs or links.

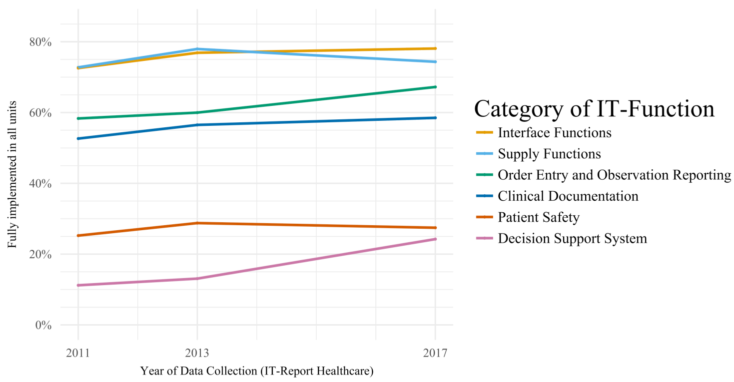

Figure 3. Display of IT adoption rates of six types IT applications for the years 2011, 2013 and 2017

6. Conclusion

We designed and implemented a system that improves data management for longitudinal analyses via the data vault model approach for persistent, historicized storage of datasets. It thus allows for agile, longitudinal analyses of heterogeneous datasets and lays the foundation of more rigorous and theory oriented studies of health IT adoption.

7. Conflict of Interest

The authors state that they have no conflict of interests.

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