Exploring Cloudy Collaboration in Healthcare: An Evaluation Framework of Cloud Computing Services for Hospitals

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Abstract

Cloud computing (CC) is regarded as having the potential to facilitate collaboration in the hospital sector. Yet, adoption of cloud computing services (CCS) in hospitals is low. While a well-designed evaluation of CCS can promote informed adoption decision-making, research on CCS evaluation in the hospital sector is insufficient. To address this research gap, we propose an evaluation framework (EF) of CCS for hospitals. Grounded in the human, organization and technology-fit model, our EF employs six dimensions to evaluate how a CCS facilitates collaboration in hospitals. By applying our EF to 38 identified CCS for hospitals, we demonstrate its efficacy. Our research contributes to both practice and research. For practice, our EF can be used to screen available CCS for hospitals and thus expedite cloud adoption processes. For research, our EF unfolds the complexity of CC in healthcare and is of particular relevance for IS research in healthcare.

1. Introduction

Cloud computing (CC) is an emerging IT service paradigm that enables users to gain on-demand access to a shared pool of configurable computing resources, such as networks, servers, storage, and applications [1]. In particular, CC is capable of enhancing the exchange and sharing of data between disparate health information systems (HIS) [2] and enables access to healthcare-related data and services from anywhere, at any time [3]. Thus, CC has the potential to address the insufficient situation of HIS (cf. Section 2.1) and create a promising future for healthcare entities by facilitating collaboration in healthcare [4].

Collaboration is a joint effort towards a group goal, in which people combine their expertise, insights, and resources and bring them to bear on the task at hand [5]. Today, organizations like healthcare entities frequently face complex problems that are not easily handled or solved by a single individual [6]. Collaboration has therefore become ubiquitous in such organizations [6]. In the healthcare industry, healthcare delivery processes are interwoven with collaborative relationships between health professionals, patients, and other stakeholders (e.g., insurers, researchers) [7]. The healthcare industry is facing challenges of rapidly increasing healthcare demands [8] but dramatically dwindling financial and medical resources [9]. As hard-hit area of these challenges, hospitals are continuously requested to cut healthcare costs while maintaining high quality of care [9]. Consequently, hospitals have begun to seek for more collaboration with each other, hoping that this will increase the outcomes of services [10], minimize duplication and wasting of medical resources [2]. These potentials can be empirically supported by, for example, a recent study, which relies on seven cases of collaboration between hospitals across eleven countries, showing that both patients and hospitals can benefit from enhanced collaboration in healthcare delivery [11].

CC is an effective means to facilitate collaboration within and between hospitals. Yet, adoption of CC in hospitals and in the healthcare industry as a whole is low [12]. In general, a main reason for the low adoption of HIS is the lacking knowledge of decision makers with respect to its potentials and benefits [13]. As for CC in hospitals, this problem might even be more serious since its adoption is particularly complex [4]. Without support, hospital decision makers cannot be expected to gain deep insights into available cloud computing services (CCS) and to get to know results of cloud adoption.

A well-designed evaluation of CCS is considered to be a sufficient way to enable informed decision-making [14]. Based on Song and Letch [15], HIS evaluation can be defined as a process used to identify, measure, and assess the value of an object (e.g., how a CCS facilitates collaboration) in a given context (e.g., the hospital sector) in healthcare. The topic of HIS evaluation has been widely discussed (cf. for example [16]). However, research on evaluation of general HIS as well as CCS in healthcare seems insufficient. Many existing evaluation artifacts of HIS are conceptualized for domains other than healthcare, often resulting in inadequate or unspecific evaluation results [16]. Notwithstanding high

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organizational complexity of hospitals and the people-centered nature of healthcare service delivery, as well as their related collaborative processes [16], existing HIS evaluation studies focus more on technical issues of HIS [17, 18]. Despite the necessity to observe HIS from an information systems (IS) perspective (cf. for example [17, 19]) only little attention has been paid to HIS evaluation from the IS domain, especially for CC in the hospital sector regarding the topic of collaboration.

To address the aforementioned research gap, our research draws on data from a literature review as well as expert interviews and proposes an evaluation framework (EF) to assess how CCS facilitate collaboration in hospitals to the IS community. Grounded in the human, organization and technology-fit (HOT-fit) model [17, 18], our EF focuses on characteristics of CCS deployed in hospitals. By applying our EF to existing CCS for hospitals identified from literature review and expert interviews, we assess and demonstrate efficacy of our EF.

2. Theoretical background

2.1. HIS and CC in hospitals

HIS are a collection of technologies and information systems for transmitting and managing health-related information in healthcare [20]. If used properly, HIS are capable of facilitating data and resource sharing between different stakeholders in healthcare [21] and can thereby promote their collaboration. Yet, traditional HIS in many hospitals are suffering from various issues; in particular, high heterogeneity and fragmentation of HIS within or among hospitals [2] and low off-site HIS availability [12] often lead to insufficient exchange of medical and patient data and thus obstruct collaborative processes within or between hospitals [2, 12]. The emergence of CC has brought new opportunities to hospitals [2], which is why it is expected to satisfy hospital's IT needs for collaboration in a more favorable way [2, 4]. In the IS domain, CC has been discussed by a wide range of research publications. These publications mainly focus on technological issues (e.g., [22]), business issues (e.g., [23]), or the conceptualization of CC (e.g., [24]) in a general context. To the best of our knowledge, there is little extant research paying attention to either evaluation of CCS for hospitals or explaining the mechanisms how CC enables collaboration in the hospital sector in detail.

2.2. The HOT-fit model

Theoretical foundation of our research is the HOT-fit model [17, 18]. The HOT-fit model builds on two established IS theories, namely the DeLone and McLean Model of IS Success [25] and the MIT90s framework [26]. The HOT-fit model is specifically designed to improve research related to HIS evaluation and its application in healthcare has been demonstrated [18]. Contrary to many insufficient IS evaluation methods (cf. Section 1), the HOT-fit model does not overemphasize the role of technology. It takes *human (H)*, *organization (O)*, and *technology (T)* factors into consideration since these three factors are regarded as the essential components of IS [18]. Each of these factors can be dissected into different dimensions. The HOT-fit model depicts that dimensions of factor *T* affect dimensions of factors *H* and *O*, while dimensions of factors *H* and *O* influence *net benefits* of a HIS (c.f. [17, 18] for more detailed explanation). Moreover, the HOT-fit model stresses the role of relationships between every two factors, which are defined as *fit* between them. In the HOT-fit context, the concept of *fit* is considered as the ability of *H*, *O*, and *T* to align and integrate with each other [17, 18].

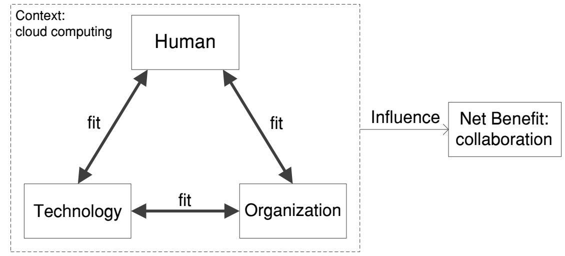

Figure 1. Adapted HOT-fit model

The HOT-fit model is rather deemed an overarching framework for HIS evaluation, and it can and should be applied in a flexible way, for different purposes, and in specific contexts [18]. Thus, we adapt it to comply with the purpose and context of our research, namely to evaluate how CCS facilitate collaboration in hospitals. As outlined in Figure 1, we consider collaboration as the *net benefit* that can be facilitated by CC. In line with its original model, our adapted HOT-fit model demonstrates that collaboration in hospitals can be influenced by CC *technology*, *humans* who use CCS, and hospitals (i.e., *organizations*) in which CCS are deployed, including their related service processes. The links *fit* are interpreted as integration and cooperation of two different factors in the model, implying the importance of collaboration between these single factors (i.e., *H*, *O*, and *T*) for the achievement of overall collaboration in hospitals.

The adapted HOT-fit model is in line with the views of a wide range of previous studies on collaboration in healthcare, which point out that human, organizational and technological factors are key participants of a collaborative activity in modern healthcare and correlation and cooperation between them are able to smoothen and thus improve the collaboration process [7, 19, 27, 28]. Therefore, we can argue that the adapted HOT-fit model is appropriate to serve as a theoretical foundation for the development of our EF.

3. Research design

We applied a three-stage approach for our research. In the first stage, we conducted a review of extant literature as well as eleven semi-structured expert interviews, thus drawing data from theory and practice. We differentiated identified data between a *training dataset* and a *test dataset*. Data from literature belonging to the *theoretical* category (cf. Section 3.1.1) was included in the *training dataset*, while the *test dataset* covered data from literature falling into the *empirical* category (cf. Section 3.1.1) and from expert interviews (cf. Section 3.1.2). Following the guidelines of Fu et al. [29], we utilized the *training dataset* to develop an EF of CCS for hospitals in the second stage. Finally, we assessed the resulting framework by applying it to identified CCS for hospitals represented by the *test dataset*.

3.1. Data collection

3.1.1. Literature review. Our literature review process was oriented towards the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines [30]. An overview of the literature review is given in Figure 2.

To identify research articles addressing the topic of CC in hospitals, we searched pertinent scientific literature databases covering a wide range of journals and conferences in the domains of IS, computer science, and medical informatics. Included databases were ACM Digital Library, AIS Electronic Library, EBSCOhost, Emerald Insight, IEEE Xplore Digital Library, Proquest, PubMed, and ScienceDirect.

We searched title, keywords, and abstract using the search string: *(cloud OR "software as a service" OR software-as-a-service OR SaaS OR "platform as a service" OR platform-as-a-service OR PaaS OR "infrastructure as a service" OR infrastructure-as-a-service OR IaaS) AND (hospital* OR clinic* OR inpatient OR in-patient)*. After removing duplicates, a sample of 3334 publications remained, which were then screened by two researchers independently.

Publications were screened using title, abstract, keywords, and full texts. Ineligible articles were excluded by applying predefined exclusion criteria. Accordingly, we excluded all articles that were not published within the last 10 years (*not up-to-date*), are *not in English*, *not peer-reviewed*, or *off-topic*. After the

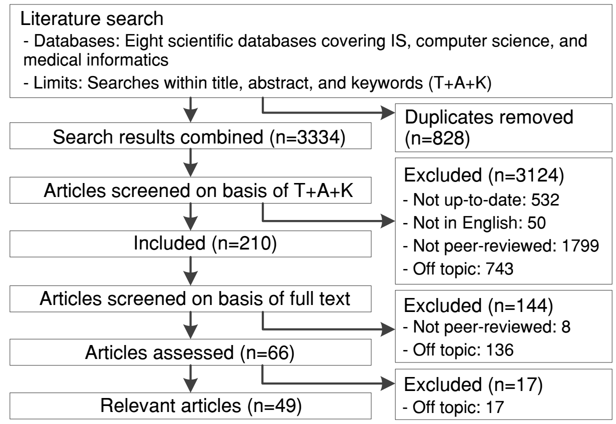

Figure 2. Flow diagram of inclusion/exclusion and literature analysis

literature screening, 3268 articles were excluded from further considerations, while 66 articles remained and were analyzed in detail.

During the analysis of remaining research articles, we identified 17 additional articles that were off-topic, resulting in a final sample of 49 articles to be analyzed in detail. Purpose of the literature analysis was two-fold. First, we pursued characteristics of CC in hospital contexts from a theoretical perspective. These characteristics represent an idealized or desired status of CCS for hospitals based on the current status of CC, providing a solid basis for the development of our EF. Second, we aimed to locate concrete applications of CC in hospitals as well as their characteristics from literature, used to assess the resulting EF. Accordingly, we classified the literature into two categories: *theoretical* and *empirical*. The *theoretical* category covered articles delivering general statements about CCS in hospitals (e.g., [31]) or proposing CCS that are not yet deployed in practice (e.g., [2]), while the *empirical* category contained articles describing concrete CCS for hospitals (e.g., [32]). We observed that some articles deliver general statements or features about CC and then apply them to concrete CCS for hospitals (e.g., [33]). These articles are rather considered as special cases of the *empirical* category and thus also fall in it. In total, 24 of the 49 eligible articles were classified as *theoretical* and 25 as *practical*.

Two researchers separately read all eligible articles to identify relevant statements related to characteristics of CCS for hospitals. Each relevant statement was extracted and turned into one or more pieces of code that represents a characteristic of the described CCS. We compared and aggregated all codes derived by both researchers in order to generate a master list of characteristics that summarizes our analysis results. In total, our master list comprises 685 codes that represent characteristics of CCS addressed by the identified literature.

3.1.2. Expert interviews. We conducted eleven semi-structured expert interviews to identify CCS and their characteristics from practice. They were used to assess the resulting EF. For conduction of expert interviews as well as for analysis of interview results, we followed the best practices by Kvale [34].

We chose experts engaged in IT activities in hospitals for our interviews, who have already used or provided CCS. Interviewees were selected with the aim of developing a diverse pool of experts to gain insights from different perspectives (see Table 1). Accordingly, we did not only include experts with a strong technical background (e.g., i07), but also those who are responsible for management on strategic (e.g., i11) or operational level (e.g., i03). Moreover, we involved an IT project manager from the local public health department (i.e., i08), who can provide insights into the perspective of governmental health authorities. On average, interviewees had a work experience of 12 years. All interviewees' organizations were located in China.

Our interviews focused on experts in China due to three reasons. First, China is a representative example of CC market that has been rapidly expanding in the past few years. A recent report by IDC [35] indicates that, in comparison to the previous year, the Chinese cloud market has increased by 61.9% in 2014 and reached USD 902.8 million. Second, the Chinese healthcare industry is accelerating the adoption and utilization of HIS [36]. As part of this effort, China is actively trying to leverage CC to enable collaboration in the hospital sector and to promote exchange and access of medical data between hospitals [36]. Third, the adoption of CC for the Chinese healthcare industry is being supported by a host of "big players" in the international CC market, including IBM, Cisco, AT&T, Microsoft, and Dell, who are believed to bring numerous existing CC products and best practices to the Chinese CC market as well as healthcare industry [36]. Therefore, we argue that CC experts from the Chinese healthcare industry are familiar with and can thus provide insights of existing CCS in hospitals for our research.

Table 1. Interviewee details

ID	Job title	Organization
i01	CIO	Hospital
i02	Head of IT Department (Dep.)	Hospital
i03	Project Manager	HIS Provider
i04	Staff at New Media Dep.	Hospital
i05	Head of IT Dep.	Hospital
i06	CEO	HIS Provider
i07	Senior IT Staff	Hospital
i08	IT Project Manager	Health Dep.
i09	CIO	Hospital
i10	Senior IT Staff	Hospital
i11	Vice Director	Hospital

Previous to the formal interviews, we developed an interview guide, which was validated and revised by two internal validation interviews. Based on the interview guide, we asked each interviewee to enumerate all concrete CCS existing in hospitals, including but not limited to those related to their own organization. Afterwards, interviewees were asked to describe how each enumerated CCS works as well as to outline all of its characteristics. These characteristics covered CCS' properties that can be utilized to facilitate collaboration in hospitals. Expert interviews were conducted between December 2014 and January 2015. They had an average duration of 59 minutes. All interviews were recorded and the recordings were transcribed.

Two researchers read the transcripts carefully to extract CCS enumerated by the interviewees and assigned the corresponding statements to each of the CCS. To ensure consistency of our data basis, both researchers applied the same coding technique as in the literature review to analyze extracted statements. As a result, we obtained a list of 221 codes representing characteristics of 13 CCS for hospitals. An overview of identified CCS can be found in the appendix.

3.2. Evaluation framework development

Our development process was guided by Fu et al. [29], who highlight that the design of an evaluation should be led by a mental model representing a basic idea of the evaluation and completed by proposing frameworks or toolkits embodying this idea. For our research, we employed the adapted HOT-fit model described in Section 2.1 as a mental model and relied on data derived from literature to develop an EF.

We focused on codes belonging to research articles in the *theoretical* category (cf. Section 3.1.1) since they reflect an idealized or desired status of CC and can serve as benchmarks for CCS in practice. Two researchers reviewed these codes and classified them into the following seven categories based on their interpretations: *H*, *O*, *T*, *human organization fit (HO-fit)*, *human technology fit (HT-fit)*, *organization technology fit (OT-fit)*, and *irrelevant*. The first six categories stand for three basic factors and their relationships in the adapted HOT-fit model (cf. Section 2.2), which can be utilized to facilitate collaboration in hospitals. For example, the code "real-time data-sharing" represents a technological feature of CCS that relates to enabling collaboration and was classified into category *T*, while the code "patient-centered service process" indicates a relationship between human and the process in an organization during collaboration and can thus be classified into category *HO-fit*. The last category *irrelevant* encased characteristics of CCS that are not directly linked to the concept of collaboration. Accordingly, codes like "flexible pricing model" and "high service level" fell in this category and were excluded from further analysis.

We successively analyzed the codes in each of the six remaining categories. Grounded in our mental model, we derived one core characteristic of CCS for each category. These core characteristics typify the features of CC that can be utilized to facilitate collaboration in hospitals. Therefore, they served as concrete dimensions of our EF to assess CCS. Based on the related codes, we also defined a three-level measurement scale for each of the derived dimensions. The measurement scale is used to assess the extent to which a CCS possesses this characteristic (dimension).

3.3. Evaluation framework assessment

We assessed the resulting EF by applying it to identified CCS from both literature and expert interviews. We used a sample of 38 concrete CCS for hospitals captured by the *test dataset*, of which 25 were identified from literature and 13 from expert interviews (cf. Section 3.1). Two researchers separately reviewed the codes assigned to these CCS and evaluated them by applying the six derived dimensions and their defined measurement scales (cf. Section 3.2) to the CCS. To ensure inter-rater reliability, we employed Janson's and Olsson's ι, a multivariate extension of Cohen's κ for multiple judges on the same scale [37], to evaluate the assessment process. As a result, we reached a score of ι=0.7385, indicating a "substantial" agreement between both researchers [38]. Differences were resolved through discussion. After the assessment process, no changes were made regarding the resulting EF in the last stage.

4. Research results

4.1. Evaluation framework description

Our EF contains six dimensions, which represent core characteristics of CC that, based on our literature review results, facilitate collaboration in hospitals. Each dimension possesses a three-level measurement scale (i.e., +, -, and ○), used to differentiate and thus evaluate a CCS's degree of fulfillment of a certain dimension/characteristic. The level "+" indicates the most desired or idealized fulfillment degree of a CCS for a certain dimension, which does not diverge from the current status of CC according to the literature, while "-" stands for the lowest possible degree a CCS could ever reach in the dimension and "○" is seen as a middle or neutral level between "+" and "-".

(a) User variety (uv). This dimension represents the factor *H* in the adapted HOT-fit model and describes properties of users of a CCS. Due to their high scalability and accessibility [1], CCS have the potential to enable a large number of different kinds of (internal or external) users (e.g., physicians, patients, families) to cooperate within a system [39], and thus to facilitate their collaboration [7]. In this dimension, a CCS is assessed as "-" if it allows only one single kind of users (e.g., physicians), as "○" if it is designed for two different kinds of users (e.g., patients and physicians), and as "+" if it supports more than two kinds of users (e.g., hospital administrators, physicians, and nurses).

(b) Process perimeter (pp). This dimension relates to the factor *O* since it addresses the process in an organization (e.g., a hospital). CC enables access to services or data, without consideration of user's geographical location [3]. This eliminates geographical constrains, expands the perimeter of a medical process, and thus promotes collaboration between different organizations [27]. In *pp*, the level "-" indicates that the process supported or realized by a CCS is limited to a single hospital, "○" denotes that the process involves a specified group of hospitals or organizations, while "+" represents a process, on which no organizational and geographical restrictions are imposed.

(c) Data sharing degree (dd). The third dimension highlights the degree of data sharing of a CCS between users and thus refers to the factor *T*. Data sharing is the essence of collaboration supported by HIS [28]. Indeed, one of the most valuable advantages provided by CC is an improved data sharing ability of HIS in hospitals [31]. Accordingly, a CCS is regarded as having "-" in this dimension if it does not support data-sharing between users, "○" if data-sharing is asynchronous, and "+" if data sharing is synchronous (e.g., real-time data exchange).

(d) Patient involvement (pi). Besides collaboration (cf. Section 1) another nature of healthcare service delivery is its customer orientation [16], implying a high demand of patient embedment in hospitals' medical processes and thus collaboration between patients and hospitals [60]. The CC paradigm is service-oriented [1] and can thus integrate the customer-oriented nature into its process. This CC characteristic is reflected in *pi*, which is in line with the view of a *HO-fit*. In this dimension, we observe a CCS as possessing "-" given that no patient involvement occurs throughout its process. If a patient is involved in the process only when necessary (i.e., passive patient involvement), a CCS is assessed as "○". A CCS with level "+" means that this CCS is patient-facing (i.e., active patient involvement, also cf. Section 5.1) [61].

(e) Device integration (di). The dimension *di* describes the ability of a CCS user device to integrate with users and thus represents the *HT-fit*. In general, a barrier impeding the use of HIS and hence also its potential of enabling collaboration is the alteration of users' traditional workflow paradigm [62]. In other words, users often have to adapt themselves to the technologies (cf. e.g., [63]) leading to reluctance to adopt HIS. CCS can be accessed by a wide range of devices [1] and thus have the potential to support devices with a high degree of integration with humans to increase their flexibility as well as possibilities to collaborate [60]. In this dimension, a CCS is assigned to "-" if it has no specific adaption to user devices, "○" if it is adapted to common mobile devices (e.g., smart phones) increasing the mobility of service, and "+" if it implements sophisticated human-computer integration technologies like sensors or wearable computer technologies enabling service access in a more unrestrained and unobtrusive way.

Table 2. Results of the EF assessment

Hospital CCS		uv	pp	dd	pi	di	si
[8]		○	○	+	-	○	+
[32]		-	○	○	-	-	-
[40]		+	-	-	-	-	○
[12]		+	○	○	-	-	+
[41]		-	-	○	-	-	-
[42]		-	○	+	-	○	○
[43]		-	○	+	-	-	○
[44]		-	○	○	-	○	○
[45]		-	○	○	-	+	+
[46]		-	-	+	○	+	-
[47]		-	-	○	-	-	○
[39]		-	○	+	-	○	-
[33]		-	-	○	-	+	-
[48]		-	○	+	○	○	+
[49]		-	-	+	-	○	○
[50]		○	-	○	-	○	-
[51]		○	-	+	+	○	○
[52]		○	-	○	-	-	○
[53]		-	-	+	-	-	○
[54]		○	-	-	+	+	+
[55]		-	-	+	○	-	+
[56], c02, c05		-	-	○	-	○	-
[57]		○	-	+	+	+	+
[58]		-	+	○	-	-	+
[59]		-	-	○	-	○	+
c01		○	-	○	+	○	-
c03		+	-	○	-	-	-
c04, c07		-	-	○	+	○	-
c06		-	-	-	-	○	+
c08		-	○	○	+	-	-
c09		○	○	○	-	-	-
c10		○	-	+	+	+	-
c11		+	○	○	-	-	○
c12, c13		+	-	○	-	-	○
∑: n (%)	-	23(61)	25(66)	3(8)	27(71)	16(42)	16(42)
	○	9(24)	12(32)	23(61)	3(8)	16(42)	12(32)
	+	6(16)	1(3)	12(32)	8(21)	6(16)	10(26)

(Note: Due to rounding, displayed percentages of one dimension might not add up to 100.)

(f) System interoperability (si). This last dimension represents the *OT-fit* view and relates to the ability of a CCS to interoperate with other processes or systems in a hospital. Interoperability is regarded as a challenge existing in many hospitals due to high heterogeneity of different data, systems, and/or processes [2]. By centrally implementing industry standards [4], cloud providers are capable of increasing the interoperability of their CCS. As a result, these CCS are able to cooperate with different systems more smoothly. A CCS is rated with "-" in *si* if it cannot interoperate with any other systems and thus works as a silo, "○" if it can only interoperate with certain predefined systems, and "+", given that it integrates industry standards for interoperability.

4.2. Evaluation framework assessment results

By applying our EF to 38 identified CCS for hospitals from both literature and expert interviews, we assess its efficacy of evaluating how CCS facilitate collaboration in hospitals. The assessment shows that our EF is applicable to all the CCS. The derived dimensions and their measurement scale can fully cover the characteristics of identified CCS, which can be utilized to facilitate collaboration in hospitals. Therefore, we demonstrate the efficacy of our EF.

Table 2 depicts the assessment results. All CCS possess the level "-" in at least one of the six dimensions. More than 60% of the CCS are assessed with "-" in *uv*, *pp*, or *pi*, and more than 40% in *di* or *si*. On average, the percentage of "+" in all six dimensions is less than 20 (18.9%). Our assessment results thus reveal an insufficient situation of addressed CCS regarding their capabilities to support collaboration for hospitals, as discussed in Section 5.

5. Discussion

5.1. Research results

Taking a look at the statistics of the assessment results of our EF (see Table 2), we gain some key insights into the existing CCS for hospitals. In *user variety*, 61% of assessed CCS enable only one single type of users, thus possessing the measurement level "-". Indeed, most of such CCS (e.g., CCS in [44, 46, 49], c02) are designed to be used by physicians. A traditional view about HIS claims that physicians are actually end-users of HIS [64]. Consequently, decision making processes for development or purchase of new HIS that are led by physicians have become a recent development in healthcare [65]. It is therefore not surprising that more CCS have been designed and developed to cater to physicians' needs, as implied by the assessment results in *user variety*. Physicians are usually trained to be self-reliant in thought and action and do not view themselves as being dependent on others in the provision of care [10]. This culture possibly inhibits the realization of desired collaborative healthcare processes enabled by CC, which take different user groups like physicians, nurses, clerical workers, and patients into account [28]. Thus, physicians' reluctance to coexist or interact with other occupational users or even other physicians in the same HIS should receive more attention in future research.

The philosophy of modern HIS has shown a hopeful scene to us: collaboration between different entities is not limited by their geographical locations; boundaries of healthcare services are rather defined by their processes [27]. This scene, however, can be realized by only one CCS, based on the assessment results for *process perimeter*. This CCS, presented by [58], enables users to search and share patient data stored in different participating hospitals without consideration of their locations. Yet, among the 37 CCS that are evaluated as "-" or "○" in *process perimeter*, nine (e.g., CCS in [12, 45, 55], c06) possess "+" in *system interoperability*. This indicates that these CCS are highly interoperable with heterogeneous IS or processes in different organizations. If improved properly, they still have the possibility to integrate with more external systems and thus effectively expand the scope of their care delivery processes.

The dimension *patient involvement* evaluates the extent to which patients are involved in healthcare delivery processes realized or supported by CCS. Only 29% (n=11) of the CCS ensure more or less patient involvement in their processes and are evaluated as "○" (n=3) or "+" (n=8). Nowadays, HIS and related IT services, like CCS, intend to alter patient behavior and change their role in healthcare delivery processes [61]. Patients try to manage their health more autonomously [27] and wish to act more actively in healthcare [61]. A health-related IT service that engages patients and promotes an active role for them can be defined as a patient-facing IT service [61]. Accordingly, there are three categories of patient-facing IT services: *information and transaction*, *expert care*, and *self-care and community* [61]. Our research addresses eight CCS that can be evaluated with "+" in *patient involvement* and thus identified as patient-facing IT services. Among them, c01, c04, c07 and c08 mainly assist patients in booking and managing medical appointments, while CCS in [54] enables patients to manage healthcare data. They can thereby be classified into *information and transaction*. CCS in c10 and [51, 57] provide remote medical consultation services to patients and are thus defined as *expert care*. Besides, CCS in [51] also interacts with external social networks and can thereby fall in category *self-care and community*. In agreement with previous research [61], we cannot identify any CCS that provides patients with "one-stop" service linking all three categories of services. This still reveals a need for further improvement of the CCS that are already regarded to provide patient-facing services based on our evaluation.

We observe that more than half (58%) of the identified CCS adapt themselves to user devices (i.e., evaluated as "○" or "+" in *device integration*). These CCS develop for example specific mobile device applications (e.g., [49]), compress data to accelerate data transfer (e.g., [44]), or implement sensor technologies (e.g., [46]) for user devices. Thereby, these CCS are most likely to increase flexibility and mobility of service access and enhance connections between users and CCS. However, use of mobile or sensor technologies in healthcare is not without challenges [60]. In a recent study, Dehling et al. [66] point out that many extant mobile health apps are probably suffering from data security and privacy issues. For CC in healthcare, data security and privacy are also seen as its Achilles' heel [4, 67]. Whether or not a combination of these technologies will aggravate data security and privacy issues in healthcare and thus impede its dissemination remains to be addressed in further research.

5.2. Contributions and limitations

Our research contributes to both practice and theory. For practice, our EF can support hospital decision makers in evaluating CCS concerning a specific topic (i.e., collaboration) and thus expedite their cloud adoption processes. Our EF evaluates CCS along six different dimensions and can, for instance, be used by hospital decision makers to screen potential CCS according to their own needs.

For theory, our research proposes a useful tool to the IS community to unfold the complexity of CC in healthcare. Our EF concentrates on CC and reflects its specificities in the hospital sector. It needs to be emphasized that our EF is not expected to also cover CCS in other areas due to its specific scope. Yet, our EF is of particular relevance for the IS community, since healthcare represents a substantially different context compared to other areas where IS research is conducted and thus deserves specific attention of IS researchers [9]. Our research is grounded in the HOT-fit model, rooted in two classic IS theories. Although our main research purpose is not to build new IS theories in healthcare, our research adapts the HOT-fit model and employs the adapted model to explain and understand the phenomena of CC in hospitals. Thus, we argue that our research can be classified in the catalog of *Health-IS* research according to Chasson and Davidson [9], in which "authors examine phenomena in healthcare context, using theory to explaining phenomena, possibly extending or building theory in this context" (p. 163). We apply our EF to evaluate CCS identified through a literature review (cf. Section 3.3). Thus, our research can also be considered as a *framework article* in the IS domain synthesizing research literature, because it "constitutes a way of understanding the research within a body of knowledge" [68, p. 41] (i.e., how CCS presented by literature facilitate collaboration in hospitals). In particular, our EF can be defined as a framework that is used to synthesize previous research in an actionable way, because it evaluates how CCS presented by literature facilitate collaboration in hospitals and highlights their strengths and improvement opportunities for researchers and practitioners [68].

The limited number of 11 expert interviews is a limitation of our research, which does not necessarily guarantee that all existing CCS in the hospital sector are fully covered. However, articles from the *empirical* category in our literature review provide us information about further CCS in practice, which can be regarded as a meaningful supplement to our expert interviews. For our expert interviews, we did not include patients on purpose, though the role of patients is an indispensable component of the hospital sector and the use of HIS [7]. Our interviews focus more on interviewees' expertise on CCS for hospitals. Ordinary patients are less likely to provide such expertise or "insider-information" about CCS for hospitals and are thus not defined as experts for our research.

It is noteworthy that our EF serves as a module in a holistic evaluation project of CCS for hospitals since it focuses only on a single aspect of CC (i.e., collaboration). Thus, its evaluation results do not necessarily represent overall quality of a CCS. Future research should make an effort to develop EF that address remaining relevant topics, like CCS' functionalities, or their financial advantages, and combine them with our EF for a more holistic evaluation of CCS for hospitals. Further research could also take specificities from other industries into account. By doing this, the scope of our EF can be expanded and our EF can thereby be utilized to address more general CCS.

6. Conclusion

250 years ago, James Watt used evaluation methods, albeit maybe informal ones, to assess the efficiency of Tomas Newcomen's steam engine [69]. This led to improvement to the Newcomen steam engine, which stands out as one of the notable landmarks in the Industrial Revolution [69]. Today, the emergence of CC is regarded as having the potential to create a promising future for HIS enabling collaboration in healthcare [4]. CC can and should play an important role in the development process of modern healthcare. However, its adoption is still lagging [12]. In this paper, we propose an EF for CCS in hospitals. With our EF, we expect to assist researchers and practitioners in gaining deeper insights into CCS for hospitals, promote their continual improvement, and facilitate adoption of CC in the hospital sector.

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Appendix. Overview of identified CCS from expert interviews

ID	**Short Description *[Source (s)]***
c01	A cloud-based clinical information system that enables patients and their relatives to book and manage medical appointments in a hospital, and allows patients to view laboratory reports related to their appointments and upload own image files to support diagnoses *[i01, i07]*
c02	A CCS that allows physicians of a hospital to view and share patient information with each other by using authorized mobile devices from both within and outside the hospital *[i01]*
c03	A cloud-based virtual desktop solution covering all information systems in a single hospital *[i02]*
c04	A medical appointment management tool that enables patients to book medical appointments in a hospital by using mobile devices and view laboratory reports related to their medical appointments *[i02, i10]*
c05	A CCS for physicians in a hospital enabling its users to directly view and share medical images on authorized tablet computers from within or outside the hospital *[i03]*
c06	A cloud-based web service used to support radiology information systems and provide enterprise-wide image processing (e.g., 3D/4D visualization) across clinical care areas *[i03]*
c07	c07 provides same services as c04, deployed, however, in another hospital *[i04]*
c08	A web-based CCS enabling patients to book medical appointments in certain top-rated hospitals *[i04, i08]*
c09	A cloud-based platform provided for small-sized hospitals in a district that enables processing and sharing electronic medical records of patients within these hospitals *[i05]*
c10	A CCS providing remote real-time medical video consultation services for patients; by using sensors, c10 collects and stores vital signs of a patient, supporting the consultation and further clinical activities *[i05, i11]*
c11	An internet-based cloud solution for hospital information systems for several dental hospitals, which integrates all standard applications and information systems of a common dental hospital *[i06]*
c12	c12 provides same services as c03 deployed, however, in another hospital *[i08]*
c13	c13 provides same services as c03 deployed, however, in another hospital *[i09]*