Towards Adoption of Standards for Communication Infrastructure/Technologies in Healthcare Systems in LMICs: Theories, Practice and Evaluation

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Abstract: While electronic health offers great promise to improve healthcare in low and middle-income countries (LMICs), the communication infrastructure/technologies (CI/T) requires standards to improve the current state of none to limited interoperability. This study reviewed theories that inform the assessment of the health system's readiness to adopt ehealth CI/T standards. The study involved a scoping review of published articles reporting adoption to the use of ICT, technologies, and standards in health. Articles published in English between 2012-2019 were identified through PubMed Central and Google Scholar. Also, grey literature from websites of WHO, standards development organisations and Uganda's Ministry of Health were searched. Data extraction involved coding to identify key themes that inform the readiness of health systems to adopt standards for eHealth CI. Of the 3,817 published articles, only 32 met the inclusion criteria. 17 grey literature was also included in our discussion. Results identified determinants for eHealth CI/T and that concepts from the technology adoption theories can be used as metrics to assess readiness to adopt standards for ehealth CI/T. The metrics for drivers to adopt standards were higher than inhibitors in Uganda's health system. The metrics will lead to the development of a readiness assessment framework.

1 BACKGROUND

Electronic health (ehealth) has lately received much attention from various health stakeholders. However, much of ehealth technological developments have remained fragmented and mostly proprietary, contributing to a lack of interoperability between health information systems and supporting technology (Fontaine et al., 2010; Neuhaus et al., 2011; Tamburis et al., 2012). Consequently, many ehealth initiatives have not scaled up (Huang et al., 2017; Kiberu et al., 2017; McCann, 2012). This greatly hinders the attainment of the ehealth key goal which is access to health information by authorised persons when and where required. According to the IEEE standards site, interoperability is the ability of a system to work with other systems without special effort on the part of the user (IEEE Website, n.d.). In this concept, interoperability allows health data / information generated by one system to be accessible and meaningfully reusable to another system, whether or not they are based on different technologies. Health system access to data or information is achieved over a communication network, which should also be interoperable. This study focuses on the interoperability of the secure communication infrastructure required to support health data transfer and information exchange (Kuziemsky and Peyton, 2016).

Communication infrastructure (CI) consists of communication hardware, software and network interfaces that share healthcare information between stakeholders (Gillwald, 2008; Yiming et al., 2016). Implementation and use of the CI should follow uniform standards across the healthcare system. *Standards* are specifications necessary for proper co-existence and interoperability of communicating systems, necessary for meeting national and international regulations (Adebesin et al., 2013; European Telecommunications Standards Institute, 2013; ITU-T, 2012). Standards are rules for common and voluntary use, decided by one or several people or organisations (Brunsson et al., 2012). Regards ehealth, standards guide the capture, storage, exchange, and secure use of ehealth information (Vincent et al., 2015; WHO, 2013). For the CI/T, the standards do describe

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accurately and unambiguously how information is transmitted over the communication systems (Eduqas, 2015); similarly, ehealth CI standards must explicitly specify how both the internal and external CI will transmit health information across the health system. Although, WHO recognises the need for electronic transmission of personal requirements to adhere to standards in health data and technology (WHO, 2013), Adebesin et al., (2013) argue that adoption must pay attention to specific requirements of a country such as the available communication resources of the communicating parties. In fact, consideration should be made of the other ehealth and communication constraints like the finance, human resources, etc required to establish and maintain such communication infrastructure. It is argued that, existing global ehealth standards may not necessarily apply to resource-constrained environments (Adebesin et al., 2013; ITU-T, 2009). In this research context, particularly CI/T, the concept of *resource constrain* will refer to data communication inhibitions including but not restricted to limited bandwidth; limited or no network connectivity; limited ICT skills; and limited power supply. Such environments provide unique infrastructure, technical, and social constraints that require innovative design approaches and need to be guided by technology standards, standardized terminologies, and data format and interoperability standards (Anderson et al., 2012).

In addition, despite multiple benefits of health information exchange (HIE) (Rahurkar et al., 2016), it is challenged with a lack of suitable CI standards (Kiberu et al., 2017; Uganda Ministry of Health, 2016). For example, in Uganda's context, a situation analysis of its health system showed that 79% of the health facilities had computers and 56% had some form of Internet connectivity (Hindemark, 2013; Kiberu et al., 2017; Ministry of Health, Republic of Uganda, 2015). However, they are stand-alone, and this, amidst a genuine acknowledgment for connectivity supporting HIE poses the need to assess readiness to adopt standards for ehealth CI/T.

Based on the definition of Rajiv and McLean, (1998) and Rogers, (1983), who define *adoption* as a formal process that may include an agreement between ehealth stakeholders to use given standards in the entire health system, we motion that to date Uganda has not yet formally adopted ehealth standards specific to the CI/T. In fact, LMICs lack guidelines, criteria, and frameworks to guide the adoption of suitable ehealth standards to support their healthcare systems. Therefore, this study reviewed existing ehealth standards and the technology adoption theories with an aim to identify the barriers and motivators to adopting standards and identify metrics for assessing the readiness of healthcare systems in LMICs to adopt standards for ehealth CI/T. Second, we used the metrics to assess the readiness of Uganda's health system to adopt standards for ehealth CI/T.

2 METHODS

Two distinguished methods were used to achieve the objectives of the scoping review and assessing readiness to adopt standards. In order to achieve the objectives of a scoping review, health informatics literature was retrieved from PubMed Central and Google Scholar. Additionally, grey literature (standards development processes and government reports) were retrieved from through website search. A full search of PubMed Central was done. The following keywords were used to retrieve relevant documents: 'electronic health', 'health information exchange', 'standards', 'health technology', communication infrastructure', and 'resource-constrained countries'. To exhaust the search, keywords were replaced with synonyms. The search retrieved 3,817 peer-reviewed articles on which we applied the inclusion and exclusion criteria in Table 1. With the exception of the definition of key concepts/theories, the study only considered publications between 2012-2018.

Table 1: Inclusion and Exclusion Criteria.

Inclusion criteria	**Exclusion criteria**
Studies that focus on streamlining healthcare systems (Health Management Information System, Electronic Medical Records, etc) to ensure HIE	Studies that only focus on health data capture, processing and storage or on research evidence, surveillance data, survey data, or other non-routine sources and types of data.
Studies that focus on standardization of ehealth CI / T, privacy and security of shared health data / information	Studies that focus on clinical health equipment / technologies
Studies on ICT, technology & innovation adoption and or diffusion-based on theories	Studies not specific to ICT technology / innovation adoption nor based on theories of adoption / diffuse
Studies that examined organizational readiness to adopt new technology / innovation	Studies that only made general consideration for adoption of technology / innovation

The authors independently coded and later agreed on the emerging themes. Key themes were refined by a discussion with experts from Uganda's MoH.

The method followed to assess readiness to adopt standards for ehealth CI/T involved the use of secondary data from Uganda's health system to assess the country's readiness. The data sources include published articles and reports from the ministry of health, NITA-U, and UCC that discuss ehealth in Uganda. We also held informal discussions with 05 experts from the division of health informatics.

3 RESULTS

3.1 Literature Review

Only 53 studies, websites, and reports were included in reporting the results of the review and subsequent discussions. Key results of the review are presented in two parts;

(A) Determinants for eHealth CI/T: Network *infrastructure* consists of the hardware and software resources for an entire network that enables connectivity, communication, operations, and management of an organisation's network (Gillwald, 2008; Yiming et al., 2016). In the ehealth information-sharing environment, *communications* include people-to-people, people-to-things, and things-to-things communications as well as the physical backbone for all e-applications (ITU and UIT, 2017). Thus, ehealth communication infrastructure includes the hardware and the software of an entire communication network, and the network backbone that supports healthcare communication. Components of the CI/T supporting HIE are shown in Table 2. Current modes of health data communication include the sharing of text, images, audio, and video (Al-Safadi, 2016; Widya et al., 2003). These are multimedia content with high communication requirements (Widya et al., 2003) requiring the ehealth CI/T and network backbone to be fast, flexible, large, reliable and with appropriate security and privacy measures (Reid et al., 2005).

Table 2: Determinants of Health System Readiness to Adopt Standards for eHealth CI/T.

CI/T components	**Brief Description**
Use of ICT networks	How the ICT network that supports healthcare is used as a contributing factor to the success of ehealth data sharing. In fact, readiness is reflected by how ehealth technology users engage in the use of existing data-sharing networks (Rezai-Rad et al., 2012).
Available hardware and software systems	The health system requires the hardware and software that support health data transmission requirements. As such the standards must be adopted for these devices, equipment, and physical security measures to harmonize the diversity and ensure interoperability.
Affordability	This is the organisation's financial capacity to acquire and maintain ehealth communication technologies. It also includes the cost of the bandwidth for health data transmission to other health institutions, cost of hardware and software, maintenance cost and human resources. Similarly, with ehealth standards, the concern is how accessible, open or affordable the specifications are to the implementors (Baker et al., 2015).
Quality of infrastructure	A measure of the quality (regards usability and performance) of the established CI/T. Inappropriate infrastructure impacts usability and performance and therefore can negatively shape the user attitudes towards health information systems (Cresswell and Sheikh, 2013). The telecommunication service provider/governments supply part of the quality. It is important to regulate the CI quality both internally (within the organisation) and externally.
Level of ICT literacy and support personnel	eHealth technology literacy levels of users and expertise of the support personnel are key in the capture, storage, and sharing of health information. Whereas the perceived high level of ICT literacy has a positive relationship to the adoption of technology (Ketikidis et al., 2012), anxiety to use of technology negatively influences such adoption (Mac Callum and Jeffrey, 2014). Equally, literacy level and support personnel influence the kind of standards adopted to guide the implementation and use of ehealth CI/Ts.
eHealth CI security & information privacy	Privacy and security concerns of patient data and or information necessitates securing the CI/T supporting HIE. The level of hardware and software security may influence security upgrades (standards) to be adopted by the health system to protect health data (Rezai-Rad et al., 2012).

(B) Technology Adoption Theories: Review of the technology adoption theories guided the selection of metrics for assessing readiness to adopt ehealth CI/T standards. Reviewed theories include;

Technology Adoption Model (TAM): TAM focuses on the motivation of a technology user, the 'perceived usefulness' and 'perceived ease of use' (Godoe and Johansen, 2012; Taherdoost, 2018). Perceived usefulness is the degree to which a person believes the use of a particular system enhances his or her job performance. Perceived ease of use is the degree to which a person believes the use of a particular system is free of effort. Although perceived usefulness results from extrinsic motivation (Godoe and Johansen, 2012) output quality and perceived ease of use (intrinsic motivation) have an impact on the perceived enjoyment and perceived usefulness (Taherdoost, 2018). This raises user acceptance of a given technology and or standard.

Technology Readiness Index: Technology readiness (TR) index is the inclination to embrace and use new technologies to accomplish routine goals (Parasuraman, 2000; Son and Han, 2011). TR are factors that foster or hinder the adoption of new technologies (Liljander et al., 2006). It has four dimensions of both positive and negative technology-related beliefs, that is, optimism (a belief that technology offers people increased flexibility, control, and efficiency), innovativeness (a tendency to be a technology pioneer and a thought leader), discomfort (a belief that one can lose control and be overwhelmed by technology), and insecurity (distrust and skepticism about technology and its ability to work properly) (Parasuraman, 2000). Whereas optimism and innovativeness are key drivers of technology readiness propelling users towards new technologies, discomfort and insecurity are inhibitors of technology readiness, which hold users back.

Diffusion of Innovation Theory (DOI): Diffusion is the process where adopters become aware of the standards over time and consider it for adoption (Rogers, 1983). DOI is a process that occurs as people adopt a new idea, product, practice, and philosophy (Oliveira and Martins, 2011). The process begins with an initial few who adapt to the use of innovation, technology or standards, then with the increase in their perceived usefulness and perceived ease of use, more people and organisations are driven to adopt its use. DOI covers the technological context (all technologies that are relevant to the organisation), characteristics of an innovation (attributes that determine the rate of adoption) (Baker, 2011), and adopter characteristics (degree of being early or late adopters of innovation) (Ramdani et al., 2013; Rogers, 1983).

Technology, Organisation, and Environment (TOE): The TOE framework has components for organisation characteristics (characteristics and resources of the organisation), technology characteristics, and environment characteristics (Baker, 2011). TOE has been used to study the adoption of different types of IT and IS innovations (Rajiv and McLean, 1998). Unlike DOI, TOE introduces environmental context besides the technology and organisational contexts of technology or innovation adoption. The environment includes industry characteristics, support structures, and regulations. The environment characteristics influence decisions to adopt and implement technological innovation in the adopter organisation, therefore play a vital role in the decision process to adopt technology and or standards.

Internet Standards Adoption (ISA): According to Hovav et al., (2004) standards adoption as represented by the ISA model is a function of the utility of the standard's characteristics (individual perspective) and the environment in which the adopter operates (community perspective). ISA framework acknowledges that besides the standards features having high utility (useful features), successful adoption requires an adoption environment that is conducive (Hovav et al., 2004). Both dimensions must be of high quality for the standard to be fully adopted. Useful features of a standard may appeal differently to potential adopters. However, ISA does not consider organisation characteristics that are fundamental to the successful adoption of technologies and or standards.

Table 3 presents a summary of the metrics derived from the related technology adoption theories (models and frameworks) that can be used to assess readiness to adopt standards for ehealth CI/T. Since none of the satisfies all the metrics, we apply suggestion of Ketikidis et al., (2012) to improved/develop a model to assess adoption in health, The study argues that components/metrics form TRI, TOE, and ISA can be integrated to assess healthcare systems readiness to adopt standards for CI/T. Thus, the study developed a framework (refer to Figure 1) that integrates evaluation metrics from TRI, TOE, and ISA to assess readiness to adopt standards for CI/T.

Table 3: Metrics for Assessing Technology / Innovation Adoption Readiness.

Theories	Technology use belief				Characteristic of adopter Organisation					Characteristics of a technology / innovation						Deployment Environment				
	Usefulness		Ease of use																	
	Optimism	Innovativeness	Discomfort	Insecurity	Mangt support	Decision process	Organisation size	Use experience	Financial resource	Availability	Regulation	Compatibility	Complexity	Trialability	Observability	Network extensity	Related technology	Install base /scope	Competitive use	External support
TAM	✓	✓	✓	✓	—	—	—	—	—	✓	—	—	—	—	—	—	—	—	—	—
TRI	✓	✓	✓	✓	—	—	—	—	—	✓	—	—	—	—	—	—	—	—	—	—
DOI	✓	✓	×	×	—	✓	—	✓	—	✓	×	✓	✓	✓	✓	✓	✓	✓	×	—
TOE	×	×	×	×	✓	✓	✓		✓	✓	✓		×	×	×	✓	✓	✓	✓	✓
ISA	✓	✓	×	×	—	✓		✓	✓	—	✓	✓	✓	✓	✓	✓	✓	✓	×	✓

Key. ✓=Support the metric; ×=Do does not support metric; — =lack of sufficient information.

(C) ***Global Standards for eHealth CI/T:*** The study identified the following about existing global standards for ehealth; One, there are many and often overlapping ehealth standards. Two, they are developed by international standards organisations, ITU and foreign governments to support ehealth. Three, existing ehealth standards, both international and national do support different dimensions of ehealth. Those aligned to ehealth CI/T supporting HIE span the breadth of communications of electronic records, digital images, clinical communications, and health information communication. They include but are not limited to ISO 12052:2017 Digital imaging and communication in medicine; ISO 13606-5 EHR communication for Interface specification; ISO/HL7 27931 for data exchange; IEEE 11073 for health devices; ENV 13606: Part 2 for archetype interchange; CR- CEN for quality of service that support health information interchange; IEEE 1073.3.x–standards for medical device communications; ISO 27799:2016 for health informatics information security management in health; ISO/DTS 14441 for security and privacy of EHR systems; CR 14301:2002 framework for security protection of health care communication; CR 14302:2002 framework for security requirements of intermittently connected devices; and ISO 17090-public key infrastructure for digital certificates (HL7 International, 2017; IEEE Website, n.d.; ISO, 2017).

(D) ***Metrics for Assessing Readiness to Adopt Global Standards for eHealth CI/T:*** The metrics in Table 3 can be customised to suitably assess Uganda's health system readiness to adopt standards for ehealth CI/T to support HIE in resource-constrained environments. The metrics are categorised in Figure 1 as characteristics of the standards for CI/T (ehealth CI/T standards), characteristics of adopter organisation (adopter environment) and standards implementation environment (implementation environment) (Hovav et al., 2004; Ramdani et al., 2013). To examine the drivers and inhibitors of organisational readiness to adopt self-service technologies, we adopted Liljander et al., (2006) ideology; that is, an organisation is likely to succeed in standards adoption in cases where there are high optimism and innovativeness (drivers for standards adoption) than discomfort or insecurity (inhibitors) in use of the standards. Drivers for standard adoption relate to the high utility, while inhibitors relate to the low utility. Besides, adopting internationally recognised standards for ehealth CI, privacy and security should in addition focus on the dynamics of resource constrained environments, in our case Uganda.

- *Standards for eHealth CI/T* – motivators for the health system to adopt standards for ehealth technology include availability of the standard; perceived advantages from the adoption of such a standard to support the existing and future technologies; complexity of application stages, severity of changes it can cause and clarity of outcomes; possible forward and backward compatibility with other standards and or technologies from other vendors; trialability and observability. Whereas trialability examines the possibility of piloting and scaling to include the entire healthcare system, observability is the

extent to which results of ongoing ehealth CI/T standards processes can be observed due to the selective perception of the beneficiary stakeholders

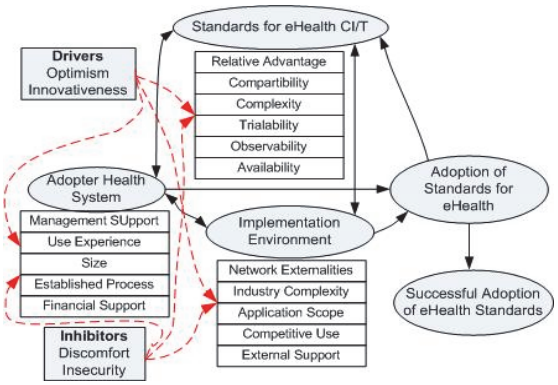

Figure 1: Framework for assessing health system's readiness to adopt ehealth CI/T standards.

- *Adopter Health System* – the health system management support, size, financing, standards use experience, and standards adoption procedure and use process, are factors that determine the readiness of the health system and personnel to successfully adopt and use the ehealth standards. To assess the existence of any established structured process for the adoption of the standard, there is a need to evaluate the management decision process to adopt and enforce the use of the standards. Also, the personnel capacity to comply with the set of standards is paramount to the overall success of any standards adoption. The organisational size and financial capability are also key influencers of adoption. A great size and a good financial capacity imply more resources can be allocated to support the adoption and implementation process (Maunder et al., 2018).
- *Implementation Environment* – the standard deployment environment imposes restrictions on what is and what isn't applicable. For example, the need for patient safety technology may limit the use of the radio frequency power levels of the medical / healthcare sensors. We examine the standards implementation environment in light of the external pressures arising from the complexity of the healthcare industry, the scope of applicability of the standard being considered across the healthcare system, the standards competitive use and the existence of any external support for the use of the adopted standard.

3.2 Assessing Readiness to Adopt Standards for CI/T

(A) CI/T Status in Uganda's Health System: As presented in Table 4, results show that existing CI/T in Uganda's health system continues to be characterized by rigid, small, slow, intermittent / unreliable and insecure connections (Huang et al., 2017; Kiberu et al., 2017; Uganda Ministry of Health, 2016).

(B) Status of eHealth CI/T Standards in Uganda: The desired state is a set of standards that satisfices all the metrics for the readiness of the health system to adopt standards for ehealth CI/T. Thus, we review current ehealth CI/T standards, both global and Uganda's as a case of resource-constrained setting. Despite their existence, these standards have received little attention in resource-constrained settings, both via limited or no participation in their development and or adoption to using (Adebesin et al., 2013; Alunyu and Nabukenya, 2018). Both authors claim there is no evidence of adoption or contextualization of global standards by LMICs in the African region.

In order to examine their claim of no evidence of adoption of ehealth standards by African countries other than the ICD codes, we assessed the status of adoption of ehealth CI/T standards in Uganda's health system. Thus, we used metrics for the evaluation of technology adoption readiness from Table 3 and obtained the result presented in Table 5. The results are based on data from government reports, MoH website, NITA-U website, and UCC regards the status and use of ICT in healthcare.

Table 4: Current and envisioned standardised ehealth CI/T for Uganda's health system.

	Current state	**Envisioned state**
Nature	Slow, rigid, small, unreliable and insecure connections	Fast, scalable, robust, reliable, secure and private connections
Charact-eristics	• Diverse network devices • Varied networked departments and services • Variation in data transmission rates • Limited/intermittent bandwidth/Internet • Varied implementation and enforcement of computer use' security measure and levels	• Standardised implementation of network devices, software, network protocols, and processes • Existence of technical and institutional interoperability

Table 5: Uganda's readiness to adopt existing global eHealth CI/T standards.

Global eHealth CI/T Standards	**Status in Uganda's eHealth Environment**	**What should the eHealth CI/T Standards be like in Uganda?**																			
		Use belief				Characteristic of adopter organisation					Characteristics of the standard						Deployment environment				
		Opt	Inn	Dis	Insec	Mgt	Proc	Size	XP	Fin	Ava	Reg	Pat	Plex	Trial	Ob	Ext	Rel	Inst	Pet	sup
ISO 11073	U, NA	✓	✓	—	—	✓	×	✓	×	×	✓	✓	✓	—	✓	✓	✓	—	✓	✓	×
IEEE1073.x-MDDL	U, NA	✓	✓	—	—	✓	×	✓	×	×	✓	✓	✓	—	✓	✓	✓	—	✓	✓	×
ISO 12052:2006	U, NA	✓	✓	—	—	✓	×	✓	×	×	✓	✓	✓	—	✓	✓	✓	—	✓	✓	×
HL7 27931:2009	NU, NA	✓	✓	—	—	✓	×	✓	×	×	✓	✓	✓	—	✓	✓	✓	—	✓	✓	×
ISO 11073-91064	NA	✓	✓	—	—	✓	×	✓	×	×	✓	✓	✓	—	✓	✓	✓	—	✓	✓	×
ENV 13606: Part2	NA	✓	✓	—	—	✓	×	✓	×	×	✓	✓	✓	—	✓	✓	✓	—	✓	✓	×
CR	NU, NA	✓	✓	—	—	✓	×	✓	×	×	✓	✓	✓	—	✓	✓	✓	—	✓	✓	×
IEEE 1073.3.x	NU, NA	✓	✓	—	—	✓	×	✓	×	×	✓	✓	✓	—	✓	✓	✓	—	✓	✓	×
PISO 27799:2016	NU, NA	✓	✓	—	—	✓	×	✓	×	×	✓	✓	✓	—	✓	✓	✓	—	✓	✓	×
ISO/DTS 14441	U, NA	✓	✓	—	—	✓	×	✓	×	×	✓	✓	✓	—	✓	✓	✓	—	✓	✓	×
CR 14301:2002	NU, NA	✓	✓	—	—	✓	×	✓	×	×	✓	✓	✓	—	✓	✓	✓	—	✓	✓	×
CR 14302:2002	NU, NA	✓	✓	—	—	✓	×	✓	×	×	✓	✓	✓	—	✓	✓	✓	—	✓	✓	×
ISO 17090	U, A Part 1, 2 & 3	✓	✓	✓	×	✓	×	✓	✓	×	✓	✓	✓	—	✓	✓	✓	✓	✓	✓	×

Key: Opt=optimism; Inn=Innovativeness; Dis=Discomfort; Insec=Insecurity; Mgt=Management support; Proc=Decision process; Size=Organisation size; XP=Use experience; Fin=Financial resource; Ava=Availability; Reg=Regulation; Pat=Compatibility; Plex=Complexity; Trial=Trialability; Ob=Observability; Ext=Network extensity; Rel=Related technology; Inst=Install base /scope; Pet=Competitive use; Sup=External support; A=adopted; NA=Not formally adopted; U=In use; NU=Not in use; ✓=satisfies; ×=does not satisfy; and — =lack of sufficient information.

4 DISCUSSION

Standards are ever-evolving in response to technological changes and health care needs. Therefore, Uganda's health system, as the adopters and implementers of ehealth standards, should recognize and adapt to changes. In this study, we needed to assess the readiness of Uganda's health system to adopt standards for ehealth by examining the adopter organisation (the Uganda health system), the adopter environment and features of the standard for ehealth CI/T. We recognise that the lack of adoption can be attributed to a lack of metrics, and or systematic procedure for adoption of standards for ehealth.

Uganda's health system is challenged by diverse network and communications systems implementations (Kiberu et al., 2017; Uganda Ministry of Health, 2016). As shown in Table 4, the health system is varied with a number of networked departments and services, data transmission rates, intermittent Internet, limited bandwidth, and different computer-use security levels, among others (Huang et al., 2017; Kiberu et al., 2017; Uganda Ministry of Health, 2016). These variations cause unnecessary delays in data sharing; data loss due to transmission errors, dropped data packets, and in worst cases a denial of service; which in the case of emergency lead to delayed service and eventual loss of life. In addition, it is clear that Uganda's healthcare few CI/T resources (Uganda Ministry of Health, 2016), the human resources lack requisite skills and technical support (Uganda Ministry of Health, 2016), lack of experience in implementation and monitoring conformance to standards that support the various dimensions of ehealth CI/T, etc. Such challenges drive the need for standardised high-capacity communication systems to handle the high-volume of healthcare data generated (Song et al., 2014). Thus, effort must be made to bridge these gaps in the standardisation of ehealth in LMICs.

The challenges are complicated by the lack of a structured procedure/process at the health system level to support the standards adoption and implementation (Ministry of Health, Republic of Uganda, 2015). Both the public and private healthcare facilities have neither reached a level of coordinated nor interoperable ehealth systems (Hindemark, 2013; Kiberu et al., 2017). Although NITA-U oversees the

standardisation of the communication and the external support for standards implementation in Uganda (NITA-U, n.d.), they have not adopted, developed and or harmonised the standards to suit ehealth communication devices and health system networks, particularly the unique nature of health data transmission required for health system communication in a resource-constrained environment (Uganda Ministry of Health, 2016). In fact, the results in Table 5 show Uganda has adopted only one set of standards i.e., standards for the public key infrastructure. This cannot work in isolation of other security or CI/T standards. Other global standards for ehealth CI/T (in-use or not-in-use) have not been formally adopted. the existing UCC communication standards for data transmission do not explicitly stipulate the minimum specifications for timely, error-free and secure data sharing requirements suitable for healthcare (Song et al., 2014). This means Uganda does not have suitable standards to support ehealth data communication requirements for their usually resource-constrained environments.

The Assessment of standards that have been developed or adopted by NITA-U as of June 2017 regards ehealth communication infrastructure show, first, gaps in the statement of minimum requirements that meet big data communication requirements for a timely, error-free and secure exchange of health data/information. Whereas health informatics should facilitate the coherent and consistent interchange and use of health-related data, information and knowledge, NITA-U only adopted ISO 17090 Part 1, Part 2 and Part 3 of the public key infrastructure for digital certificates. Second, exposed component areas of the ehealth communication infrastructure without standards / minimum specifications to guide implementation and compliance monitoring. Examples include network capacity, quality of service parameters, communication equipment, etc suitable for healthcare data sharing; and third, show a lack of consistency in the structure/presentation of standards. This shows inconsistency in procedure and manner in which the standards are developed or adapted. The December 3rd – 4th (2012) WHO forum on health data standardisation and interoperability discussed perspectives on the health data standards implementation (WHO, 2012). They relate to the five antecedents of organisational readiness to adopt information systems identified by (Aziz, 2012), which include desired change, leadership support, organisational context, attributes of change target and IT support and can be mapped to the three dimensions of the TOE.

Furthermore, the lag between published standards and their implementation means that future adoption and implementation should be a continuous and cyclic process. Assessment of the health system level of preparedness to adopt ehealth standards can guide their decisions to adopt and use standards. Moreover, ehealth standards adoption can be motivated by the likelihood to realise the lasting benefits of such adoption. The benefit of the adoption is a measure of the success of adoption and in future studies, we will explore the potential ehealth standards adoption success for resource-constrained settings.

5 CONCLUSIONS

This study argued that existing global standards (developers are commonly from high-resourced environments) may not apply as is to resource-constrained settings common in LMICs. Thus, need to be contextualised for applicability in resource-constrained work environments. However, there is lack of suitable metrics to assess readiness to adopt and or adapt the global standards. Therefore, the study reviewed ehealth literature to establish determinants of ehealth CI/T and security and metrics of ehealth standards adoption. The identified metrics (16 adoption readiness metrics) for assessing readiness to adopt standards for ehealth CI/T were used to assess the readiness of Uganda's health system to adopt 13 global standards related to ehealth communication infrastructure and security measures to support HIE. Based on the situation analysis of Uganda's health system as an example of LMICs, it is a promising mechanism to determine the readiness to adopt standards for ehealth CI/T for LMICs.

Although the identified metrics for assessing readiness to adopt standards for ehealth CI/T seem adequate in guiding the health system's adoption decisions, they may not in the current form support the adoption and adaption processes nor determine the "structure" of standards suitable for LMICs. In addition, the review might have been limited by incomplete retrieval of research on adoption or diffusion of standards (not indexed by PubMed Central and Google Scholar) or any reporting bias by literature considered in this review. Future research will focus (1) on developing and validating the readiness assessment framework for ehealth CI/T standards adoption readiness and exploring the potential adoption success with an aim to contextualise it for Uganda's resource-constrained health system. (2) Determining the criteria for selecting standards for ehealth CI/T that resourced-

constrained settings like Uganda's healthcare system may use to select suitable global standards to support their HIE. (3) Develop a structured process to guide the adoption and adaption of ehealth CI/T standardisation efforts within Uganda's health system.

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