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Conceptualizing a Holistic Evaluation for Interoperable Health Information Systems

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CONCEPTUALIZING A HOLISTIC EVALUATION FOR INTEROPERABLE HEALTH INFORMATION SYSTEMS

Research paper

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Abstract

Evaluation of information systems is crucial in solving challenges, informing policy and measuring return on investments in information systems. This paper carries out a systematic literature review in the evaluation of interoperability in health information systems and utilizes the parsimonious Delone and Mclean Success Model to present its findings. Key among the evaluation measures identified were standardization, scalability, security and privacy, data consistency, Vendor support, system efficiency and quality of care. The review further identified organizational interoperability as an area that has been understudied by evaluation studies and therefore calls for more research in areas like organizational structure, leadership support and politics. This paper contributes to both research and practice by identifying areas and measures to be adopted while carrying out evaluation of interoperable health information systems.

Keywords: Health information systems, Interoperability, Evaluation, Success.

1 Introduction

Health information systems (HIS) have increasingly been adopted with the goal of improving quality of care through use of health data (Gheorghiu & Hagens, 2016). This upsurge of e-health technologies in different information systems, applications, and devices show key transformations happening in healthcare (Gay & Leijdekkers, 2015). As a result, organisations are now attempting to improve health outcomes through harnessing of data accumulated from these technologies (Baseman et al., 2017). Despite continuous efforts to improve healthcare with the use of technology, unfortunately, many of such e-health systems are not interoperable meaning they cannot exchange information as seamlessly and efficiently as desired, which has posed a great problem for these organisations (van Velsen et al., 2016). Consequently, efforts are being put into creating interoperable systems today that do not only accentuate the potential of e-health systems but also lead to secondary use of data accumulated from such systems in research, teaching, and managing healthcare where powerful data analytics are carried out (EHealthNetworkMWPsub-group, 2017).

The developments witnessed so far, however, have not been without challenges. A report by the EU eHealthStakeholderGroup (2014) pointed out that achieving interoperability in healthcare information systems is a complex venture that is yet to be fully actualized. In advanced technological countries, such as Sweden, Lövström (2019) states that interoperability is only "halfway there". In the United states, Holmgren and Ford (2018) point out that efforts to promote interoperability and data sharing in Electronic Health Records (EHR) have been unsuccessful. But just how is success for such interoperability ventures measured?

Early reviews of evaluation studies for health information systems by Van der Loo et al. (1995) and Urbach et al. (2009) concluded that it was a daunting task to carry out evaluation for such systems. This is because the systems were so varied that evaluation measures and methods were dependent on the characteristics of specific systems under review. To this day, both researchers and practitioners continue to face the difficult task of evaluating success of information systems (DeLone & McLean, 2016;

Teixeira et al., 2017) much less for specific aspects like interoperability. On the other hand, given that HIS promises to improve both individual and population health outcomes, evaluation is of utmost necessity as it ensures that use of these systems yields optimal results and, in some cases, identifies unexpected outcomes (Rigby et al., 2009).

With recent research in healthcare information systems being focused on achieving interoperability (Durneva et al., 2020), the objective of this paper is to present a systematic literature review on understanding the impact of interoperability in HIS, particularly focusing on critical elements that are used to measure its success. The review has potential implications in influencing both practitioners and researchers to find better means of evaluating success for healthcare interoperability projects. The Delone and McLean (2003) success model shows a theoretical potential as an organizing framework for this study and shall further be evaluated for the specific metrics applied in interoperable HIS. This is particularly important because DeLone and McLean (2016) point out that the model is naturally dependent on the nature of the system and the organization under review, hence measurement metrics differ from one system to another.

Therefore, the research question to be investigated in this paper is: *What metrics identified from existing research can be considered for the holistic evaluation of success in Interoperable Health information systems?*

This paper is structured as follows; a theoretical background is presented to capture the basis of what interoperability is along with its definition. This also lays the foundation to adapt the DeLone and McLean model. Then, methodological steps are introduced that give a description on how the literature review took place with a presentation of the findings. A discussion and implications are then highlighted, followed by conclusions and ideas for future work.

2 Theoretical Background

2.1 Defining Interoperability

The definition of interoperability has notably evolved over time. Earlier definitions focused on the technical aspects of information systems while recent definitions have been inclusive of the other aspects of interoperability and its outcome. For instance, in 2004, the European interoperability Framework (EIF) defined interoperability as *"the capability of two or more hardware devices or two or more software routines to work together"(CompTIA, 2004).* Their definition has changed over time, and in 2017, the same commission defined it as *"the ability of organisations to interact towards mutually beneficial goals, involving the sharing of information and knowledge between these organisations, through the business processes they support, by means of the exchange of data between their ICT systems"(newE*IF, 2017). Clearly, there has been a shift into viewing interoperability as a complex venture that does not solely rely on the technical functions but business functions as well.

For the context of HIS, this paper shall adopt the definition by the Healthcare Information and Management Systems Society (HIMSS), which defines interoperability as the capability of information systems across organizational and regional boundaries to exchange and integrate data with the goal of providing convenient portability of information to optimize health outcomes across the globe (HIMSS, 2020).

The new European interoperability framework (newEIF, 2017) which was developed to comprehensively address the challenges faced in achieving interoperable systems within the EU public sector defines four layers on which interoperability has to happen. The framework acknowledges that all four layers are integral in fully achieving interoperability. They are described in table 1 below.

No.	Interoperability Layer	Description
1	Legal interoperability	Achieved when organizations working under different legal jurisdictions, policies and strategies are able to collaborate. In such situations, care has to be taken to ensure that existing legislations are not contradicted and sometimes, new legislations are required to deal with the differences.
2	Organizational interoperability	Achieved when organizations align their business processes, obligations and expectations to realize goals that are mutually beneficial and commonly agreed upon. This means that business processes should be properly documented, integrated and relevant information passed on to stakeholders. Organizational interoperability also ensures that the requirements of the users are met by easing access to the services and making them easily identifiable and user centric.
3	Semantic interoperability	Achieved when the exact format and meaning of data exchanged is preserved and understood by all the exchange parties. In the newEIF (2017), semantic interoperability covers both semantic and syntactic aspects. Semantic aspect focuses on the meaning of data through development of standard vocabularies to ensure data is well understood as intended while syntactic interoperability focuses on the format of the data exchanged in terms of grammar and format.
4	Technical interoperability	Achieved when different systems and infrastructures are able to communicate. Its aspects include interface specifications, interconnection services, data integration and presentation services and security protocols. A major obstacle is pointed to be legacy systems which were built from bottom -up to solve specific problems which has led to the rise of systems fragmented in silos. Technical interoperability can be attained through the use of widely accepted formal technical specifications.

Table 1. Interoperability layers based on the new European interoperability framework.

So, is success for HIS achieved only when the four layers of interoperability are achieved? Or how is it otherwise measured? The following section explores extant literature on success measurement for information systems and discusses the Delone and Mclean (D&M) IS success model that will be adopted by this review.

2.2 Information systems success

The increasing cases of highly publicised failures of large investment Information systems (IS) ventures brought up questions of success measurement in IS (Ballantine et al., 1996). A Survey carried out by Verner et al. (2006) showed that only 62% of IS projects in the USA were deemed successful. Wide world, there is a consensus that IT-related projects show unsatisfactory success rates and always bring less value than expected (Alter, 2013). There however exists no single definition of success for information systems, as success depends on the stakeholders in an organization(Urbach et al., 2009) and the type of system being evaluated (Seddon et al., 1999). In healthcare, information systems are mainly judged for their impact on patient care (Van Der Meijden et al., 2003).

Defining success in information systems has been a daunting challenge to both researchers and practitioners. In their review, Urbach et al. (2009) established that definitions were dependent on an author's perception; Bailey and Pearson (1983) defined success as "management's desire to improve productivity of the information systems", Byrd et al. (2006) defined it as the improvement of organizational performance brought about by lowered costs while Lucas (1978, p. 29) argued that success is the usefulness of a system. These authors however acknowledge that different stakeholders could have different interests in the same system and thus different perceptions of success. Taking this

into consideration, Kim et al. (2002) defines Information systems (IS) success as "a measure of the degree to which the person evaluating the system believes that the stakeholder is better off."

Increasing technological advancement in information systems makes their benefits more intangible and measures of their success become harder to establish (Finlay, 1993). With projects as complex as interoperability which requires different stakeholders, defining success even becomes harder. Sicotte and Paré (2010) likens interoperability projects to a puzzle whose pieces can be identified but has little to work with when piecing it together. However, several researchers have argued that the fundamental role of IT in organizations does not change and proposed methodologies for measuring success in Information systems (DeLone & McLean, 1992; Finlay, 1993; Seddon, 1997; Seddon et al., 1999; Delone & McLean, 2003; Davis, 1989). These models are based on the idea that success is not an arbitrary variable but dependent on key fundamentals like veracity, timeliness and usefulness.

While Delone and Mclean (2004) further argue that the laws of economics have not been rewritten and therefore measurement of success for information systems should hold across boundaries, this is not entirely true for health information systems as their objectives transcend over making profit. In proposing an evaluation framework for HIS, Yusof et al. (2006) further introduced the "concept of fit". Here they argued that human and organisational issues play a big role in the success of HIS and thus an evaluation model should fit both into stakeholder needs and organizational needs. O'leary et al. (2015) concurred with this but opted to propose an evaluation framework implemented through the perspectives of different stakeholders. Both frameworks are however, grounded in (Delone & McLean, 2003).

This study also predicates on the DeLone and Mclean (D&M) IS success model as the organising framework. The widely adopted and cited model is based on DeLone and McLean (1992), a study that sought to address the multi-dimensional nature of success by presenting a framework of six (6) interdependent constructs, "System Quality, Information Quality, Use, User Satisfaction, Individual Impact, and Organizational Impact".

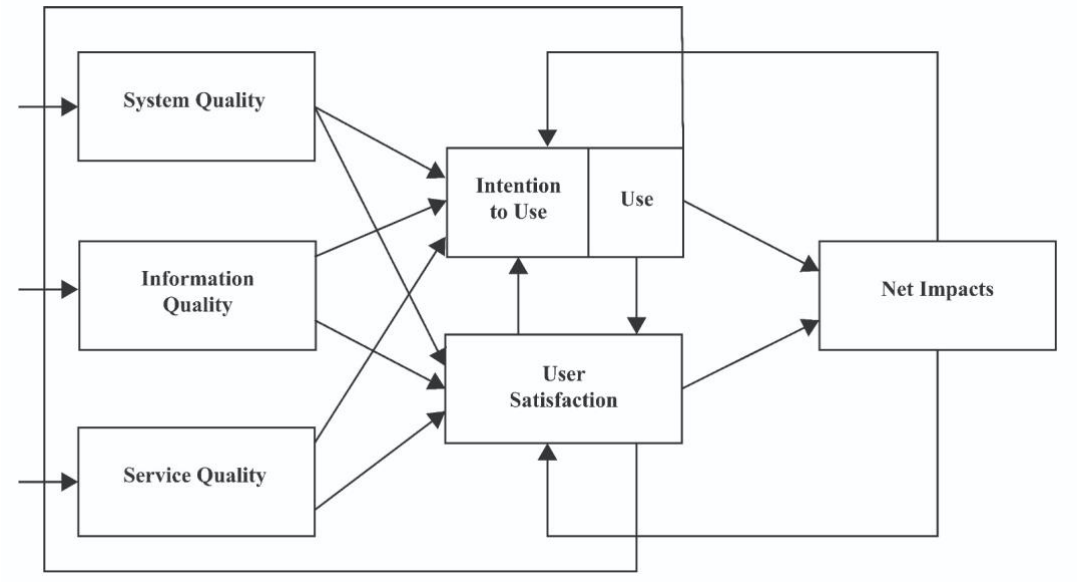

Figure 1. Adopted from (DeLone & McLean, 2016)

After more than 285 published papers cited, assessed, criticised and validated the model, notably, (Seddon, 1997), it was subsequently revised by Delone and McLean (2003). The updated D&M IS success model shown in figure 1 above, brought in the key construct of service quality and merged the individual and organizational impact into Net impacts.

According to Delone and McLean (2003), the quality constructs of system, information and service are evaluated or controlled for separately as they influence the use and user satisfaction of the system, they

further suggested the incorporation of " intention to use" as an alternative to "use" due to the different interpretations of the word use. Furthermore, they point out that "use" always comes before "user satisfaction" but that higher user satisfaction will also lead to greater use. Finally, as a result of the use and user satisfaction, net impacts will be realised.

For the purpose of this review, the constructs are defined in the healthcare context as follows;

1) ***System Quality***—features of an HIS that are desirable for effective information exchange. For instance, a system that is reliable, flexible, easy to learn and has good user experience design is desirable.
2) ***Information Quality***-- characterized by the output of an HIS. Accurate, concise, complete, timely, relevant, and usable information is desirable.
3) ***Service Quality --*** the quality of support and training given to users by the systems vendor or the IT support team.
4) ***Use—***the measure of the extent to which a system's capabilities are utilized by the intended users. It can also be evaluated as the "*Intention to use"* which determines factors for potential users to become actual users or by the "*nature of use"* which denotes the different ways in which a system is utilised
5) ***User Satisfaction—***the measure of the user's level of satisfaction with the system.
6) ***Net Impacts—***the measure of the degree of impact the information system has on all stakeholders, like health outcomes or cost savings.

Some studies on HIS interoperability have evaluated the relationship between some of these constructs. For instance, Daskalakis and Mantas (2008) evaluated the relationship between system quality and information quality with both and use and user satisfaction. On the other hand, other studies have focused on the levels of interoperability (technical and semantic) as evaluation metrics (Khennou et al., 2017). The two approaches, however, overlap in their evaluations. For instance, the system measure construct can be equated to the technical level of interoperability while information construct can be equated to the semantic level of interoperability. This study is aimed at aggregating metrics for the holistic evaluation of interoperable HIS.

3 Methodology

The systematic literature review adopts the procedures by Wolfswinkel et al. (2017) and Webster and Watson (2002). Both these studies provide structured and easy to adopt guidelines for literature reviews in the IS field. With the goal of carrying out a developmental review, the study shall encompass a structured search strategy and adopt a concept-centric analysis grounded in previous research (Templier & Paré, 2015). As Webster and Watson (2002) point out, this does not only allow one to expound on previous research but also makes a chart for future research.

3.1 Definition

First, the criteria for inclusion and exclusion were defined. The fields of research were then identified, and appropriate sources determined. Lastly, specific terms of search were decided upon. Both empirical and conceptual studies from peer-reviewed journals were considered without a restriction on the search period. As HIS interoperability is an interdisciplinary topic that encompasses management in both health and information systems, top-tier journals from these fields were considered. First, the top six journals recommended by the Association for information systems (AIS) Special interest Group in Health (SIGHealth) were surveyed. This is because a field's major contributions are likely to be found in leading journals (Webster & Watson, 2002). The journals surveyed were: Journal of American Medical Informatics Association (JAMIA), International Journal of Medical Informatics (IJMI), Journal of Medical Internet Research (JMIR), Health Systems, BMC Medical Informatics and Decision Making and IEEE Journal on Biomedical and Health Informatics. A further search was then done on google scholar to capture eligible papers that had been identified from citations in the first search.

Since all the AIS recommended journals are health-based, only the terms “Interoperability” OR “information exchange” AND “Impact” OR “Success” OR “effective” were used to query the database.

3.2 Search

The six (6) journals were searched by the proposed keywords. The key words “Success” did not yield meaningful results when used together with either “interoperability” or “health information exchange”. A quick scan of the articles led to the inclusion of the keyword “Evaluation” as most articles discussing measurement of success used the word evaluation. This consequently yielded most of what was considered to be meaningful results. The modified query is shown below,

“Interoperability” OR “information exchange” AND “Evaluation” OR “Impact” OR “Success” OR “effective”

3.3 Selection

Fig 2 Shows the process. The initial search yielded a total of 854 articles from the six journals which resulted into 471 articles after filtering out the duplicates. The articles were then imported to Rayyan, a web-based software for literature review. Here, the titles and abstracts of the individual papers were read and selected based on the following criteria:

Include: articles discussing the evaluation of interoperability/Health information exchange in HIS.

Maybe: articles discussing evaluation of general HIS

Exclude: articles that do not cover evaluation studies.

120 articles on the *include* list were read through in full text where some were dropped immediately when it was realised that they did not meet the study objectives, 55 articles were selected for inclusion and the rest were dropped, including articles classified as maybe. A few articles (4) were later included directly from backward citations.

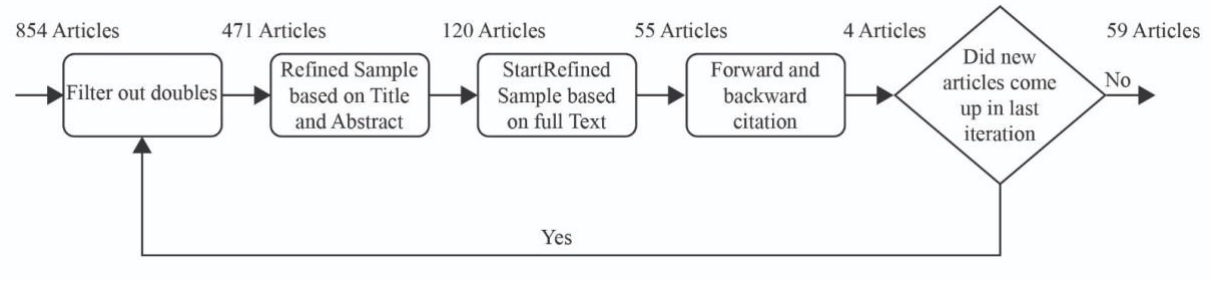

Figure 2. Adapted from Wolfswinkel et al. (2017)

3.4 Analysis

Content analysis was first carried out deductively as outlined by Hsieh and Shannon (2005) and Elo and Kyngäs (2008). During the full text reading where the final articles were selected, the articles were also concurrently organized under the appropriate D&M IS success model constructs (system quality, information quality, service quality, use, user satisfaction and net impacts). However, two articles, Holmgren and Ford (2018) and Wendel and Edberg (2015), could not be categorized under the D&M’s success model despite the fact that both articles were discussing the evaluation of interoperability in HIS. They were therefore, set aside for later review.

Articles organised under the D&M IS success model constructs were further inductively analysed. They were read through again, as notes were taken through open coding, the codes were further grouped together under broader categories that represented similar meanings, this was done until the author was satisfied that the final categories represented all the conceptualised evaluation metrics without duplication.

The two remaining papers were inductively analysed through a similar process, notes were taken through open coding which resulted into identification of organizational structure as an evaluation metric. Based on knowledge gained from reading earlier articles, the author was convinced that this should be organized under a new construct of organizational influence. This is because other metrics that could appropriately fall under this construct like political and cultural environment had been passively mentioned in other articles.

4 Findings

The final codes generated from the inductive analysis process represents metrics to be considered for evaluation of interoperable HIS. The conceptualized evaluation metrics are organized under the D&M IS success model as shown in table 2 below with their respective references.

System Quality	
Scalability	(Bahga & Madisetti, 2013; Pita et al., 2018; Qiao et al., 2020; Staes et al., 2009; Eason & Waterson, 2013; Clarke & Steele, 2014)
Data integration	(Bahga & Madisetti, 2013; Huang et al., 2018; Sittig et al., 2005; Lapsia et al., 2012)
Communication standards	(Lasierra et al., 2014; Schiza et al., 2019; Pfaff et al., 2019; Shrivastava et al., 2021)
Security and privacy	(Bahga & Madisetti, 2013; Qiao et al., 2020; Ranchal et al., 2020; Ribeiro et al., 2014; Somolinos et al., 2015; Zhuang et al., 2020; Shrivastava et al., 2021; Anani et al., 2017; Tharmalingam et al., 2016; Clarke & Steele, 2014)
User experience design	(Bianchi et al., 2014; Gazzarata et al., 2014; Hoffman et al., 2018; Lasierra et al., 2014; Macis et al., 2020)
Performance	(Feldman et al., 2013; Gazzarata et al., 2014; Laleci et al., 2013; Staes et al., 2009; Tharmalingam et al., 2016; Clarke & Steele, 2014)
Information Quality	
Accuracy	(Pita et al., 2018; Abad-Navarro et al., 2020; Tharmalingam et al., 2016; Dixon et al., 2013; Bruland et al., 2014)
Completeness	(Daskalakis & Mantas, 2008; Dixon et al., 2013; Sittig et al., 2005; Abraham et al., 2011; Bruland et al., 2014; Byrne et al., 2014)
Timeliness	(Dixon et al., 2013)
Data Consistency and Standardization	(Bahga & Madisetti, 2013; Bianchi et al., 2014; Gazzarata et al., 2014; Hoffman et al., 2018; Honko et al., 2016; Laleci et al., 2013; Roehrs et al., 2019; Pellison et al., 2020; Pfaff et al., 2019; Peterson et al., 2020; Daskalakis & Mantas, 2008; Bruland et al., 2014; Byrne et al., 2014)
Content availability	(Tharmalingam et al., 2016; Abraham et al., 2011; Byrne et al., 2014)
Reusability	(Feldman et al., 2013; Anani et al., 2017)
Service Quality	
User training	(Shachak et al., 2013; Fecher et al., 2020; Tharmalingam et al., 2016)
Vendor Support	(Shachak et al., 2013; Tharmalingam et al., 2016)

Use	
Intention to use	
Privacy and security concerns	(Grundstrom et al., 2020; Kisekka & Giboney, 2018; Salleh et al., 2021; Vanneste et al., 2013; Esmaeilzadeh & Sambasivan, 2017; Byrne et al., 2014; Campion et al., 2013; Eason & Waterson, 2013)
User characteristics	(Campion et al., 2013; Esmaeilzadeh & Sambasivan, 2017)
Level of participation in project	(Sieverink et al., 2019; Esmaeilzadeh & Sambasivan, 2017)
Consent preferences	(Grundstrom et al., 2020; Esmaeilzadeh & Sambasivan, 2017)
Availability	(Ilie et al., 2009; Sittig et al., 2005)
Nature of use	
Reusability	(Zhuang et al., 2020; Byrne et al., 2014; Feldman et al., 2013)
Effective use	(Salleh et al., 2021; Campion et al., 2013)
User satisfaction	
Ease of use	(Bianchi et al., 2014; Macis et al., 2020; Abbasi et al., 2020; Tharmalingam et al., 2016; Strauss et al., 2015; Campion et al., 2013; Hyppönen et al., 2014; Grundstrom et al., 2020; Abraham et al., 2011; Kisekka & Giboney, 2018; Byrne et al., 2014)
Competence and skills	(Shachak et al., 2013; Hyppönen et al., 2014)
Net impacts	
Quality of care	(Piera-Jiménez et al., 2020; Chouvarda et al., 2019; Kisekka & Giboney, 2018; Tharmalingam et al., 2016; Sittig et al., 2005; Abraham et al., 2011; Kash et al., 2017)
Secondary Usage	(Feldman et al., 2013; Huang et al., 2018; Qiao et al., 2020; Somolinos et al., 2015; Savage & Savage, 2020; Shrivastava et al., 2021; Staes et al., 2009; Sittig et al., 2005; Abraham et al., 2011)
Cost-benefit analysis	(Chouvarda et al., 2019; Tharmalingam et al., 2016; Sittig et al., 2005; Bruland et al., 2014; Walker et al., 2005)
Service accessibility	(Chouvarda et al., 2019; Tharmalingam et al., 2016)
Efficiency	(Tharmalingam et al., 2016; Sittig et al., 2005; Abraham et al., 2011)
Organizational influence	
Organizational structure	(Feldman et al., 2013; Wendel & Edberg, 2015; Holmgren & Ford, 2018; Aquino Shluzas et al., 2014)

Table 2. Matrix based on the modified Delone and McLean (2003) Constructs and review.

4.1 System Quality (SQ)

Scalability can be defined as the ability of a system to be configured in different locations, sizes and within an organizations' economic budget. A scalable system is considered ideal if it can conform to the legacy systems at minimal cost. Studies argue also for loosely coupled over tightly coupled systems as they are more adaptable to scaling up or down as and when needed (Eason & Waterson, 2013; Staes et al., 2009; Bahga & Madisetti, 2013). As an approach for achieving scalability, building modular systems

is encouraged with precedence given to transactional processes over analytic processes In such cases it is encouraged to consider architecture as a business decision rather than a technological decision.(Wendel & Edberg, 2015). In Evaluating scalability of Atlymo, a probabilistic linkage tool on data from Brazil's health and other public sectors, Pita et al. (2018) measured the average time spent on pulling data for single entities. On the other hand, Bahga and Madisetti (2013) evaluated scalability of their system by observing the response time while pulling different sizes of data sets on different computing capacities.

The level of *data integration* is also considered as a measure, with the desired level being the ability to integrate both structured and unstructured data from as many sources as possible. Bahga and Madisetti (2013) outlines the data integration process where data from different sources is converted into a *"flat file"* for uniformity on retrieval. Since patients, especially with chronic conditions are likely to see more than one physician or even service providers in one visit Lapsia et al. (2012) measured the level of data integration by evaluating access to and modification of a single patient record at different service points.

Communication standards are considered crucial in enabling interoperability within health information systems and different standards have been developed specially to facilitate sharing of information. Standardization is however, not seen as an exclusive measure as different systems adopt different standards for reasons other than performance. The choice of standards has been due to economic reasons and proximity. Nevertheless, standardization plays the grounding role in enabling communication in interoperable systems as its through standards that integration engines are able connect to external systems (Macis et al., 2020; Lasierra et al., 2014; Laleci et al., 2013). Some of the widely adopted standards include Digital Imaging and Communications in Medicine Committee (DICOM), Fast Healthcare Interoperability Resources (FHIR) and openEHR.

With information sharing comes *privacy and information security concerns* and therefore systems are to be built in compliance with the law. Legal frameworks like Health Insurance Portability and Accountability Act (HIPPA) and General Data Protection Regulation (GDPR) requires system vendors and providers to assure their customers of security and confidentiality through system features like authentication, identity management and secure data transmission (Bahga & Madisetti, 2013; Macis et al., 2020; Ranchal et al., 2020). Furthermore, health data is highly sensitive, and studies have recommended systems developed should be able to instil trust in users. Qiao et al. (2020) discusses traceability to information source as an important security measure.

Another key metric that is widely discussed is *user experience design.* Usability and friendliness of user interfaces is of utmost importance for HIS. Usability tests like heuristics and think aloud are used in determining how systems responded intuitively to its users. Service oriented architectures (SOA) and Representational state transfer (RestFul) architectures are widely discussed as possible solutions to user design problems in health information systems (Daskalakis & Mantas, 2008; Gazzarata et al., 2014; Bianchi et al., 2014; Lasierra et al., 2014).

Lastly, just like other information systems, the *performance* of infrastructure or computing resources is evaluated through processing times, uptime or stress tests. For instance, Feldman et al. (2013) observed reduced case processing time after the introduction of the health information exchange at Social Security Administration(SSA), a result that was termed as "a game changer" by the SSA's CIO.

4.2 Information Quality

This has been the most discussed and studied construct within HIS studies. The studies are emphatic on the importance of information quality, perhaps due to the "life and death" nature of information processed in healthcare. Most patient-centric studies reviewed argued that patient safety is highly dependent on the *accuracy* of information conveyed and systems have to be evaluated to ensure that correct information is collected and processed. Accuracy assessment approaches like the usage of gold standards and sensitivity analysis are suggested (Pita et al., 2018). Here, accuracy is also considered as a precursor to re-usability of such information and highly accurate data is subsequently deemed to be highly re-usable.

The studies further argue that accuracy of information is not enough if it's not complete. *Completeness* is the degree to which all information pertaining to a data set is accessible. Studies to measure completeness of data have been done by analysing patient records for the recommended minimum of either administrative or diagnostic data or both (Bruland et al., 2014).

Data consistency means that similar datasets accumulated from different sources have the same meaning. The level of semantic interoperability ensures that data is not only exchanged among different sources but that it's intended meaning is maintained. Different from System Quality which measures the actual exchangeability, standardization under Information Quality ensures that meanings are maintained as information moves through different channels. Consequently, Standards have been developed to ensure that information exchanged through such systems is not only legible but understandable. Fast Healthcare Interoperability Resources (FHIR) and Health Level seven International (HL7) are some of the standards that have been adopted to facilitate the standardization of information. Furthermore, clinical terminologies and diseases are being coded and unified through standardized languages by entities like International Classification of Diseases (ICD)and Systematised Nomenclature of Medicine Clinical Terms (SNOMED CT).

Systems are also assessed for their *timeliness* and delays, especially those that require real-time messaging as their availability and timeliness is crucial. Information transmitted through such systems is evaluated against delays, whether it is sent in real-time or at designated times in batches. In healthcare, delayed information will not only cost money and time but could cost lives.

Finally, the systems are also evaluated for *availability of content* to ensure that information is always accessible as and when needed. This is done through searchability and relevance tests (Tharmalingam et al., 2016). Just like accuracy, the consistency, availability and timeliness of data are considered to be precursor measures to *reusability* this data.

4.3 Service Quality

This was the least studied construct from the review, but not surprising as service is hardly a quantifiable measure. Most studies mentioned it in passive, for instance, Campion Jr et al. (2013) mentions that organizational commitment and staff training may have affected user behaviour towards the health information exchanges. Only one study, Fecher et al. (2020) considered *user training* as a measure by assessing the impact of training health IT professionals and clinical specialists by looking at re-admission rates in the emergency department. A physician in the study stated after training that they were able to *"find discharge summaries from hospitals that do not always send them to them. This is very important for hospital follow-up."*

Vendor support and responsiveness were also mentioned (Tharmalingam et al., 2016; Fecher et al., 2020).

4.4 Use

While frequency and duration of use have been widely adopted as a measure for IS use, studies reviewed seem to have moved away from these metrics. This could be due to the fact that while these measures are true for IS systems like e-commerce, time spend on a HIS is not synonymous with great outcomes in healthcare. Instead, *the intention to use* and the *nature of use* have been considered.

Intention to use is a measure of users' attitudes towards systems. Studies point out that users' attitudes towards a system depend on the *user characteristics*, for instance whether one is a physician, a radiologist or a public health official. Patients and clinicians have been the most discussed user groups. The review further indicates that user's intentions are influenced by their *perceived security and privacy concerns*. Patients are the most sceptical about sharing and raise concerns about the safety of their health data against unauthorized access. On the other hand, clinicians and service providers are most concerned about the usability of the systems and its effect on workflow processes. Patients also have preferences over the consent they give for the re-use of their information and it's therefore advisable to ensure that the systems build trust amongst the users. Esmaeilzadeh and Sambasivan (2017) found out that most

patients prefer to have full access to their information categories and are uncomfortable with their data being shared for purposes other than clinical. To evaluate users' attitudes towards an integrated healthcare project among the Flemish community in Belgium, Vanneste et al. (2013) adopted the unified theory of acceptance and use of technology (UTAUT).

The *level of participation in a project* is also a key indicator of the user's intention to use the system. Users who are highly involved in the projects usually have positive attitudes towards the systems.

Availability of infrastructure and user devices for the information exchange is also considered as a measure. Users should be able to access the systems through various devices available to them.

Under the **nature of use** *Reusability* was considered as an evaluation measure where data is used for purposes other than the reason it was collected for. For instance, Feldman et al. (2013) established that almost two (2) million US dollars were recovered over a year by the Social Security Administration (SSA) after using data from the Virginia Health Information exchange. Sittig et al. (2005) further suggested measuring frequency of access to patient records by persons other than the originator.

Lastly, Salleh et al. (2021) discusses measuring *"effective use"* as the ability of users to carry out their tasks without making significant errors.

4.5 User Satisfaction

Studies reviewed pointed out that the construct of use always precedes user satisfaction and naturally adopted *ease of use* as the measurement metric for user satisfaction. With different user groups, care should be taken to ensure that the satisfaction surveys are tailored. For instance, while clinicians are asked about the system's user friendliness, providers are concerned about the system's integration into the workflow processes, A physician using a veteran HIE had this to say "*it expedites my workflow. Unnecessary tests don't have to be ordered. We can move patients through the ER more quickly if we don't have to repeat tests or X-rays"* (Byrne et al., 2014). On the other hand, in a study by Abbasi et al. (2020), the researchers found out that despite the physician's satisfaction with the integrated imaging systems, there were still problems with its implementation. For users who are patients, they are evaluated for their trust levels in the systems. The review further established several usability tests that are used in determining ease of use for HIS such as Cognitive walkthrough, Heuristic evaluation and think aloud methods.

The level of *user competence and skills* also affects user satisfaction. Users who have undergone training or those with expertise are expected to have higher satisfaction (Strauss et al., 2015; Abbasi et al., 2020). In Shachak et al. (2013), users who were recently trained on an HIS were more satisfied than users who had received the same training early on.

4.6 Net Impacts

In analysing impacts, Delone and McLean (2003) advices researchers to analyse from stakeholder perspectives. While there exists a lot of stakeholders to HIS including patients, clinicians, providers and third parties, this review organized impacts by their perceived bearing on quality of care, secondary usage and accessibility. From healthcare providers perspectives, profitability and workflow efficiency are considered.

Interoperability in HIS is expected to improve the *quality of care* given to patients by both providers and public health agencies. In assessing health outcomes, studies suggested to analyse re-admission rates, length of hospital stays, morbidity rates and care delivery rates as indicators.(Tharmalingam et al., 2016; Sittig et al., 2005; Abraham et al., 2011)

Another outcome expected from interoperability of HIS is *secondary use* of health data where data is used for purposes other than that for which it was collected. Studies have evaluated decision support systems, research outcomes, outcomes from public health agendas and even other public agencies like Feldman et al. (2013).

With interoperability, wider *accessibility* of health services by all stakeholders is expected. Patients, expect to be able to conveniently access some services on their devices, clinicians expect to conveniently access services and patient information, while providers expect that interoperable systems increase efficiency in workflows.

Lastly as a majority of studies pointed out that implementing interoperability is a costly process that requires major financial commitment from investors. Like any other investment, organization carry out *cost- benefit analysis*.

4.7 Organizational influence

Wendel and Edberg (2015) brings in a new dimension when it comes to evaluating HIS. Although healthcare is a public service, some countries like the USA allow for the private provision of healthcare services which brings in the issue of competition between privately funded and government funded health information exchanges (HIEs). They further established that despite massive funding, government HIE's were developing slowly and called for a change in their *governance structure*. Holmgren and Ford (2018) also established that interoperability adoption varied widely across different hospital organizational structures. The two studies show that organizational structure is an important considering during evaluation.

5 Discussion- Evaluating interoperability in Health information systems

Reviewing literature against D&M's success model has provided a lens through which this paper has been able to identify evaluation metrics for interoperability projects in HIS by providing a systematic methodology. However, the model is highly contextual and therefore careful attention is needed when defining and measuring specific metrics. DeLone and McLean (2016) also advises both researchers and practitioners to measure all the six constructs or ensure other constructs are controlled when evaluating success of an information system. This is because failure to account for the all the six constructs fails in providing a holistic understanding of the system or reports confounding results.

While some evaluation metrics established from the review could be generalized to other information systems, some metrics are specifically linked to interoperability in HIS. For instance, *standardization, data integration and data consistency* are evaluated through communication standards established in healthcare like DICOM, openEHR and HL7. In evaluating *security and privacy,* compliance checks to applicable laws in healthcare are also very specific and elaborate.

In alignment with the model, the six constructs are not dependent but interdependent. For instance, one of the major factors identified under the intention to use the system was perceived security and privacy concerns which consequently affected *use*. Kisekka and Giboney (2018) found out that increased privacy concerns were associated with reduced use of the EMR while trust in the system was associated with increased use and perception of patient quality. On the other Feldman et al. (2013) discovered that fixing a security feature (authorization to disclose information) into the system, increased user's perception of security. The constructs are, therefore, highly interdependent hence the need for holistic evaluation.

While the model has provided a parsimonious framework for evaluating interoperability in HIS, it has not been efficient in evaluating organizational interoperability as established by the (newEIF, 2017). Majority of the studies pointed out the need for stakeholder involvements as a grounding requisite for success, but none of the studies actually carried out an evaluation. This weakness of the model was also pointed out (Yusof et al., 2006) who proposed the inclusion of human and organizational factors in evaluating HIS projects. From the newEIF framework, the aspects of the different interoperability layers are dully evaluated by the model as shown below.

newEIF framework	D & M Model
Technical Interoperability	System quality metrics like performance and scalability are used in evaluating a system's technical interoperability.
Semantic Interoperability	Information quality metrics like Completeness and Standardization are used in evaluating a system's semantic interoperability.
Legal interoperability	Privacy and security metrics do not only evaluate a system's legal interoperability across jurisdictions but also impacts the system's actual use.
Organizational interoperability	?? None of the metrics identified under the D& M model can be used to evaluate organizational interoperability

Table 3. Comparison between EIF framework and D&M Model on interoperability evaluation.

The review has made apparent the fact that organizational layer is not covered by the model and only one study evaluated the impact of organizational structure on data sharing in hospitals (Holmgren & Ford, 2018). The study established that centralised hospital systems where a central system makes physician or insurance arrangements, is more likely to engage in all the four layers of interoperability as opposed to decentralised hospital systems.

Traditionally, information systems have always been evaluated from a technology viewpoint which asses the hardware, software and communications, however with interoperability and linking of devices across multiple organizations, it's imperative that evaluations are also carried out from organizational perspectives. While the construct of service quality touches on organizations, it's not sufficient as organizational interoperability goes beyond provider support. Instead, evaluation should focus on socio-technical factors that affect interoperability. Such factors could include support from the leadership, project management teams, IT team support and environmental factors like organizational culture, vision, politics and financial incentives. One way of embedding organizational evaluation into the D & M model would be to substitute the service quality with organizational influence which will imply that all organizational factors including service are evaluated.

6 Conclusion

To answer the research question, this paper has identified specific metrics for evaluating interoperability projects within health information systems from existing literature. The metrics have been organised under the Delone and Maclean model which was found effective for presentation. The review further established that organizational interoperability in healthcare has not been widely addressed compared to the other aspects, even the existing evaluation literature has not provisioned for this aspect. Subsequently, the paper has proposed the inclusion of "organizational influence" as a construct for evaluating organizational interoperability and thus calls for future research to develop and test the construct.

By conceptualizing the extant literature on information system success and adapting it in the healthcare context, this paper contributes to the development of a systematic methodology for evaluating complex projects in healthcare, especially in interoperability. Achieving interoperability within HIS does not only depend on technological factors like scalability and standardization but is also impacted by organizational policies. Therefore, evaluating success as the dependent variable in information systems is an important aspect for both research and practice in the field.

The study acknowledges that the deductive content analysis applied in this review could blind a researcher, but care was taken in reviewing the selected articles to capture all concepts. The review was also carried out by a single researcher, and this could arguably bias both the inclusion criteria and the analysis, but care was taken to ensure the included article merited the review objectives and so was the analysis process. Lastly, metrics presented are only conceptual and therefore urges for further empirical evaluation, both qualitatively and quantitatively.

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