

Evaluating and Addressing Interoperability Constraints in Health Information Systems for Enhanced Healthcare Delivery in Zimbabwe

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Abstract

Interoperability constraints in health information systems pose significant challenges to the seamless exchange and utilization of health data, hindering effective healthcare delivery. This paper aims to evaluate and address these constraints to enhance healthcare delivery. The study examines the current state of interoperability in health information systems, identifies the key constraints, and explores their impact on healthcare outcomes. Various approaches and strategies for addressing interoperability constraints are discussed, including the adoption of standardized data formats, implementation of interoperability frameworks, and establishment of robust data governance mechanisms. Furthermore, the study highlights the importance of stakeholder collaboration, policy development, and technical advancements in achieving enhanced interoperability. The findings emphasize the need for a comprehensive evaluation of interoperability constraints and the implementation of targeted interventions to promote seamless data exchange, improve care coordination, and enhance patient outcomes in healthcare settings.

Keywords

Health Information System, Interoperability, Interoperability Constraints

1. Introduction

Health Information Systems (HIS) play a crucial role in the efficient and effective delivery of healthcare services. Interoperability, the ability of different sys-

tems and devices to exchange and use health information, is essential for seamless coordination within the medical domain. However, numerous constraints hinder the achievement of interoperability in health information systems, limiting the potential benefits of health data exchange. This research aims to explore and identify the key constraints to interoperability and propose effective strategies to address them, ultimately improving healthcare delivery.

Healthcare is information-intensive; vast amounts of information are created in the course of a treatment process and access to this information is very important in the continuing care of the patients. The advancements in Information and Communication Technologies (ICTs) in healthcare have created new ways of managing patient information through the digitization of health-related information. Significant investments have been made towards the implementation of mHealth applications and eRecord systems globally. However, fragmentation of these technologies remains a big challenge, often unresolved in developing countries [1].

The fragmented medical information needs to interact and be accessed by healthcare practitioners in a uniform and transparent way, anywhere and anytime, as required by the treatment path of the patients. For instance, healthcare providers need to exchange information on patient medical reports, such as clinical notes, observations, laboratory tests, diagnostic imaging reports, treatments, therapies, drugs administered, allergies and letters, x-rays, and bills. However, the information may be heterogeneous in terminology, schema, syntax, semantics, data types and data formats, hence the need for a health information system interoperability framework.

[2] assessed the integration of health information systems in a regional context and highlighted the importance of interoperability between different systems and emphasized the need for standardized data formats and protocols. The study revealed that integration facilitated the exchange of information between primary care providers, specialists, and public health agencies, leading to improved population health management and disease surveillance. [3] argued that integration is not just technical or organizational; it instead means bringing together data, organizational behaviour, workforce and policies. [4] examined the integration of health information systems in a large hospital setting. They found that the integration allowed for real-time access to patient data across departments, enabling healthcare professionals to make informed decisions quickly. However [5] argued integration is a challenging process because information systems are built differently, run on different databases, and developed in different programming languages and operating systems. In addition, they do not communicate with each other, a result of a lack of standards messaging standards. The construction and employment of Health Information System can improve the efficiency and quality of healthcare work. A health information system is broadly defined as a system that integrates data collection, processing, reporting, and use of the information necessary for improving health service effectiveness and efficiency through better management at all levels of health ser-

vices [6]. These systems, contribute to a better coordination of care, better organization of information, timeliness, accuracy and completeness of information, the ability to analyze information, reduce medical errors, reduce costs, continuity of care, information exchange, quick and easy access to providers and information in different places and times, and the improvement of the communication between health professionals and patients [7].

Interoperability on the other hand refers to the ability of different information technology systems and software applications to communicate, to exchange data accurately, effectively, and consistently, and to use the information that has been exchanged [8] [9]. The lack of interoperability leads to redundant, disorganized, disjointed, and inaccessible medical information, that may affect the quality of care provided to patients and waste financial resources [10].

Hospital's medical information is not interchangeable and accessible to other health institutions. In most situations, the health professionals do not have access to the whole of the patient's medical information unless the patient is conscious and can provide the information that the health professional requires to make an informed and individualized decision on the best course of action at the time [11]. To make an informed decision on which procedures to follow, a healthcare professional needs access to information distributed across various institutions [12]. If an institution makes an error due to a lack of information, overcoming the problem will be more difficult, if not impossible [13]. Accordingly, there is an urgent need to develop integration mechanisms among the various health information systems to allow for ubiquitous access to patient health information [14]. The sharing of information among different levels of healthcare has a link to the quality, efficiency, and safety of care provided to a patient [15]. The ability of systems to connect and exchange information with each other, in either implementation or access, without limitation refers to interoperability [16].

Problem Statement

The lack of interoperability between healthcare systems hinders the seamless exchange of health information, perpetuating the existence of information silos prevalent in the medical domain [17]. This situation leads to private ownership over health data, limiting medical information sharing, tele-consultation capabilities, and the overall efficiency enhancement of hospitals [18]. This research aims to contribute to the existing body of knowledge on health information systems interoperability by identifying the key constraints and coming up with an Interoperability Constraints Theoretical Framework to enhance service delivery in the medical domain. By enhancing interoperability, healthcare organizations can improve care coordination, reduce medical errors, enhance patient safety, and enable more efficient and evidence-based decision-making.

2. Health Information System Interoperability Constraints

The lack of interoperability in healthcare refers to the inability of different

healthcare systems, devices, and applications to effectively exchange and use health information [19]. It is a significant challenge that hinders seamless communication and collaboration among healthcare entities, leading to fragmented care and inefficient processes. Several studies have highlighted the consequences and underlying issues associated with the lack of interoperability in healthcare [20].

2.1. Access Control Constraints

Access control is a critical feature of healthcare information systems. It is about enforcing rules to ensure that only authorized users get access to resources and information in a system. Such information sharing however raises security and privacy concerns that require appropriate access control mechanisms to ensure Health Insurance Portability and Accountability Act (HIPAA) compliance [21] [22] investigated access control constraints and their implications in healthcare information systems. They highlighted the significance of access control models, policies, and mechanisms in protecting sensitive patient information and maintaining data confidentiality.

However, the top priority is always to provide the best possible care for a patient. User Authentication is one major Access constraint to health information systems, often restricted to authorized users. User authentication mechanisms, such as usernames, passwords, and multi-factor authentication, ensure that only authenticated individuals can access the system. In emergency or otherwise unexpected situations, clinicians need to be able to bypass access control. In a crisis, availability of information takes precedence over privacy concerns [23]. Protecting patient privacy is important, but the most important goal is to provide the best possible care for patients, which depends on the clinicians having access to information. Hence, access control is a balance between confidentiality and availability [24]. This is what makes access control in healthcare systems so challenging and interesting as a research subject.

Furthermore Consent and Privacy Settings, involving obtaining patient consent for accessing their health information. Patients may have the ability to specify who can access their data and set privacy preferences, such as restricting access to certain healthcare providers or specifying the purposes for which their data can be used [25].

Lastly, there are, physical access controls constraints, such as locked server rooms, access card systems, and biometric authentication, can prevent unauthorized physical access to health information systems. It has become clear that many access control mechanisms implemented in existing systems are too static, in the sense that access rules rarely change or are updated after a patient is admitted [26]. Access usually depends on what ward a patient is admitted to, where a user is working and the profession (doctor, nurse etc.) of the user. However, the care process for a patient is dynamic and individual.

To improve access control, and minimize the use of exception access mechan-

isms, access control should be process-based tailored to workflows in healthcare and dynamic in the sense that access rules change or are updated as the care process changes [16]. It is important for healthcare organizations to implement robust access controls to prevent unauthorized access, data breaches, and privacy violations. These constraints help ensure that health information is accessed only by authorized individuals and that patient privacy and data security are maintained [21].

Summary of Access Control Constraints

Access control in healthcare information systems ensures only authorized users access sensitive patient information, balancing confidentiality and availability. Key mechanisms include usernames, passwords, multi-factor authentication, and physical controls like locked server rooms. In emergencies, clinicians may bypass controls for patient care. Consent and privacy settings manage patient permissions. Dynamic, workflow-based access controls are crucial to minimize exceptions, prevent unauthorized access, and maintain data security and patient privacy.

2.2. Cognitive Overload Constraints

Clinical decision-making is essential for effective patient care and has been studied for decades but research on how EHR use influences clinical decision-making is comparatively limited. Prior researches demonstrates that physicians, irrespective of professional training, have significant, non-overlapping blind spots in EHR use, manifesting as an inability to recognize critical patient safety issues [22]. Failure to see blind spots during EHR use partially explains why medical errors are among the leading cause of death [23]. In the context of health information systems, cognitive overload can be a significant constraint that affects healthcare professionals' ability to use the systems effectively and efficiently [24].

Health information systems often contain vast amounts of patient data, clinical guidelines, research papers, and other medical information across the medical domain. Healthcare professionals may feel overwhelmed by the volume and complexity of information they need to process and interpret. Too much information presented simultaneously can lead to cognitive overload, making it challenging for users to locate relevant information or make decisions efficiently [25]. Furthermore, it might take more time in accessing the information and may be a challenge especially in cases of emergencies.

Summary on Cognitive Overload Constraints

Clinical decision-making is crucial for providing quality patient care, although the impact of electronic health record (EHR) use on decision-making has limited research. Studies indicate that regardless of professional training, physicians exhibit blind spots in EHR use, leading to potential patient safety issues and contributing to medical errors. Cognitive overload, caused by the vast amount of patient data and medical information within health information systems, can

hinder healthcare professionals' ability to effectively utilize the systems. Overwhelming amounts of information can lead to difficulty in processing and interpreting data, ultimately affecting decision-making efficiency and timely access to critical information, particularly in emergency situations.

2.3. Usability and Skills Constraints

Usability and skills constraints in interoperability refer to the challenges and limitations faced by users, such as healthcare professionals and IT staff, when interacting with interoperable health information systems [26]. These constraints encompass difficulties in using the systems effectively, lack of necessary skills or training, and inadequate user experience design. Here are some references that discuss usability and skills constraints in interoperability. Health information systems (HIS) with complex user interfaces can be difficult to navigate and use efficiently. A cluttered or confusing interface, unclear labels, and non-intuitive workflows can lead to user frustration and errors.

It therefore becomes of paramount importance for HIS to require users to have a certain level of technological literacy. Users who lack familiarity with computers, software applications, or specific technologies may find it challenging to navigate and utilize the systems effectively. In addition, Systems that do not prioritize user-centered design principles may not align with the needs, preferences, and workflows of the end-users [27]. This can result in systems that are difficult to learn and use effectively. This can also be because of Insufficient Training. Inadequate training programs or resources can impede users' ability to acquire the necessary skills to effectively utilize health information systems [28]. Users may struggle to understand system functionalities, interpret data, or perform specific tasks, leading to reduced efficiency and suboptimal system utilization.

Summary on Usability and Skills Constraints

Usability and skills constraints in health information systems (HIS) hinder healthcare professionals and IT staff due to complex interfaces, lack of training, and poor design. Cluttered, non-intuitive workflows cause frustration and errors, while inadequate technological literacy makes systems hard to use. Systems that ignore user-centered design principles and insufficient training further reduce efficiency and effective utilization

2.4. Infrastructure Constraints and Network Connectivity

Many low-income countries have limited infrastructure and network. In rural communities, the foundational infrastructure and network are even more limited compared to major cities and towns. Infrastructure constraints and network connectivity are crucial aspects of interoperability that can affect the seamless exchange and sharing of health information between different systems and stakeholders [29].

These constraints encompass limitations in hardware, software, network in-

frastructure, and connectivity issues that can hinder the effective transmission and accessibility of data. HIS rely on robust and reliable infrastructure to function effectively. As defined by [30], an IT infrastructure as, “the composite of hardware, software, network resources and service components that support the delivery of business systems and IT-enabled processes”. In this context, it is perceived that concepts like configuration management, version control, monitoring, logging, storing, backup, inventory, documentation and task manager are the infrastructure services that support the operation and management of the IT environment of an enterprise. Reliable and high-speed internet connectivity is also essential for the seamless operation of health information systems [31].

However, in some regions or rural areas, internet access may be limited, unstable, or expensive. Poor internet connectivity can hinder real-time data exchange, remote access to systems, and interoperability with external interfaces. Health information systems often require specific hardware components, such as computers, tablets, or mobile devices, to access and utilize the system. Limited availability or outdated hardware can impact the user experience, system performance, and overall efficiency of healthcare professionals [32].

Summary on Infrastructure Constraints and Network Connectivity

Low-income countries, especially rural areas, often face significant infrastructure and network connectivity challenges, which are crucial for the interoperability of health information systems (HIS). These challenges include limitations in hardware, software, network infrastructure, and connectivity, which hinder effective data transmission and access. Robust and reliable infrastructure, comprising hardware, software, network resources, and service components, is essential for HIS to function effectively. Key infrastructure services include configuration management, version control, monitoring, and backup. Reliable high-speed internet is also crucial, but many rural regions have limited, unstable, or expensive access, impeding real-time data exchange and remote access. Additionally, HIS require specific hardware like computers and mobile devices, and limited or outdated hardware can negatively impact user experience, system performance, and healthcare efficiency.

2.5. Interoperability Standards and Protocols Constraints

Standards and protocols play a crucial role in ensuring interoperability in health information systems. There are over 40 different SDOs in the health IT arena. Interoperability utilizes standards, interfaces and protocols to connect systems using appropriate techniques, methodologies and all associated issues such as legislation, agreements, governance, workflows and privacy concerns [33]. It can be achieved at various “levels” (technical, syntactic, semantic, organisational and legal).

Interoperability standards and protocols constraints refer to the challenges and limitations associated with the adoption and implementation of standard formats, protocols, and specifications for seamless data exchange and interope-

rability between different health information systems [34]. These constraints encompass issues related to the compatibility, consistency, and adherence to interoperability standards. One of the primary constraints is the lack of standardized data formats, coding systems, and terminologies. Different health information systems may use different standards, making it challenging to exchange and interpret data accurately. Without consistent and widely adopted standards, interoperability becomes difficult to achieve [35].

The presence of multiple standards and versions within the same domain also create interoperability challenges. Health information systems may be designed based on different versions of standards, leading to incompatible data formats and structures. This can result in data discrepancies and hinder effective data exchange. Some standards may have limited scope, focusing on specific data elements or use cases [36]. This limited scope can hinder comprehensive interoperability as different systems may require additional data elements or functionalities not covered by the standards. Incomplete or insufficient standards can impede seamless data exchange. Furthermore, Standards and protocols continuously evolve to keep pace with technological advancements and changing healthcare needs. However, the rapid evolution of standards can create challenges for interoperability [37]. Systems built on older versions of standards may face difficulties in integrating and exchanging data with systems using the latest versions.

Even when standards exist, there may be gaps in their implementation or interpretation across different systems. Variations in how standards are implemented or understood can lead to inconsistencies and hinder interoperability [38]. Lack of adherence to standards or non-compliance with specifications can impede effective data exchange. When different systems use different standards or versions, mapping and translating data between them can be complex. The need for extensive mapping and translation processes adds complexity, cost, and potential for errors [39]. Inefficient mapping methodologies or lack of automated tools can hinder seamless interoperability.

Summary on Interoperability Standards and Protocols

Standards and protocols are crucial for interoperability in health information systems, but face challenges such as lack of standardization, multiple standards and versions, limited scope, and evolving standards. These issues create compatibility problems, data discrepancies, and complex mapping needs, making seamless data exchange difficult. Implementation gaps and inconsistent adherence further hinder effective interoperability.

3. Methodology

This research will use a mixed methods approach to evaluate and address interoperability constraints in health information systems (HIS), combining quantitative data analysis with qualitative exploration of stakeholders' perspectives across various healthcare settings for a comprehensive understanding.

Quantitative data will be gathered using questionnaires developed specifically to assess the current state of interoperability and the specific constraints faced by HIS. These questionnaires will be distributed to healthcare professionals, IT administrators, and other relevant stakeholders, covering topics such as the types of systems in use, data exchange capabilities, challenges experienced, and the perceived impact on healthcare delivery. The collected data will be analyzed using statistical techniques like descriptive statistics to summarize the data and inferential analysis to identify common patterns and trends [40]. This will provide an overview of the extent of interoperability constraints and their impact on healthcare delivery, quantifying the challenges and identifying areas needing intervention.

To gain deeper insights, qualitative data will be obtained through semi-structured interviews and focus group discussions with key stakeholders, including clinicians, IT managers, policymakers, and healthcare administrators [41]. These methods will explore the experiences, perspectives, and specific challenges related to interoperability constraints. The interviews and discussions will be transcribed and analyzed using thematic analysis, which will involve coding the data to identify recurring themes, patterns, and key insights [42]. This qualitative analysis will provide a nuanced understanding of the specific challenges faced by different stakeholders and help identify potential strategies for addressing these constraints.

Based on the findings from both quantitative and qualitative data analyses, potential interventions and strategies for addressing interoperability constraints will be identified. These may include the adoption of standardized data formats, implementation of interoperability frameworks, policy development, and technical enhancements [43]. These interventions will be developed in consultation with relevant stakeholders and experts to ensure they are practical and effective.

The developed interventions will be piloted and implemented in selected healthcare settings, and their impact on addressing interoperability constraints and enhancing healthcare delivery will be assessed through a combination of quantitative and qualitative evaluation methods. Data will be collected before and after the implementation of the interventions to measure improvements in data exchange, care coordination, and patient outcomes [44].

Ethical approval will be obtained from the relevant research ethics committee to ensure the study is conducted ethically. Informed consent will be obtained from all participants, and their privacy and confidentiality will be maintained throughout the study. Data security measures will be implemented to protect sensitive information and ensure compliance with relevant regulations and standards [45].

In summary, this research aims to comprehensively evaluate and address interoperability constraints in HIS through a robust mixed-methods approach, involving detailed data collection, analysis, intervention development, and rigorous ethical considerations.

4. Results

4.1. Health Information System Interoperability Constraints

Healthcare practitioners were invited to address questions giving their responses according to the effect that various constraints posed to them in carrying out digital healthcare collaboration amongst service providers. The question was, “Please select from the options below which score factor (from 1 to 5) ranking the effect of the given constraints in eHealth systems interoperability. Where 1 represents less effect and 5 represents most effect”. The question listed 19 factors as constraints which needed practitioners to rate the extent of effect on a Likert scale with values ranging from 1 to 5, where 1 stood for *Least effect* and 5 stood for *Most effect*. The analysis described the frequencies of suggested responses as displayed graphically in “Figure 1”.

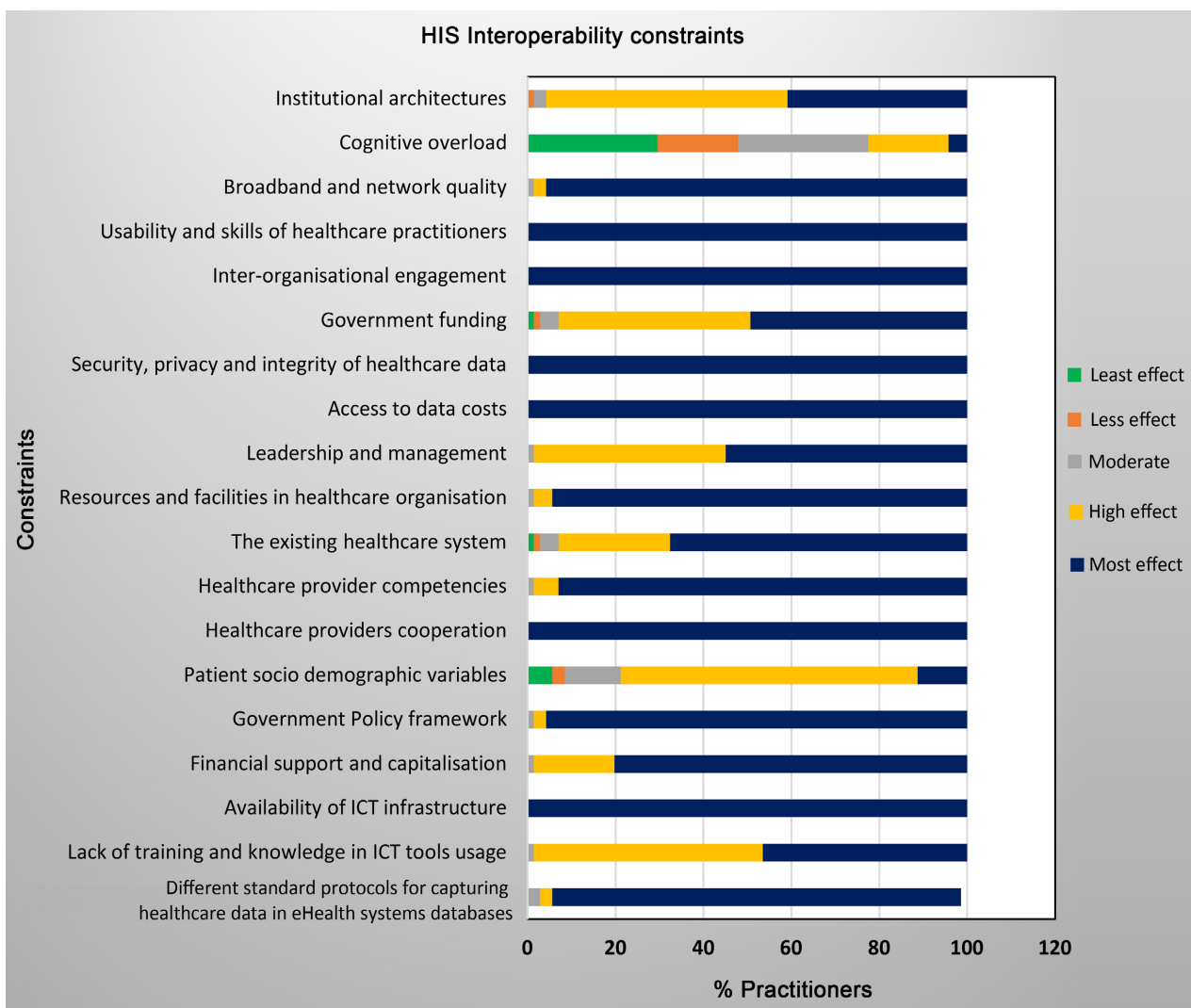


Figure 1. HIS interoperability constraints.

From the results, it can be withdrawn that the constraints the topped the list

with frequencies of 100% are availability of ICT infrastructure, healthcare providers' cooperation, access to data costs, Security, privacy and integrity of data, Inter-organisation engagement and Usability and skills of healthcare practitioners.

However, some healthcare practitioners felt that there are some factors that had least effect though with small but significant frequencies which are cognitive overload (29.58%) and patient socio-demographic variables (5.63%). Generally healthcare practitioners coincided to consider all the other 18 factors to be constraints apart from the cognitive overload factor which showed mixed views to the factor by the evenly spread frequencies of most effect (4.23%), high effect (18.31%), moderate (29.58%), less effect (18.31%) and least effect (29.58%). This shows that healthcare practitioners do not see cognitive overload or the abundance in information availability as a constraint but rather as a resource that enriches healthcare service collaboration.

For the "Interoperability Constraints" theme, Reliability test was carried out and the Cronbach's alpha is $\alpha = 0.372$, which indicates a very low level of internal consistency for the scale in this specific theme as shown in **Table 1**.

Table 1. Reliability statistics.

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
0.372	0.432	13

Table 2. Item total statistics.

Item-Total Statistics					
	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
INC_1	54.1286	8.461	0.195	0.321	0.341
INC_2	54.5571	8.540	0.105	0.148	0.360
INC_4	54.2286	8.498	0.172	0.271	0.345
INC_5	54.0714	9.285	-0.127	0.195	0.395
INC_6	54.5857	6.594	0.194	0.157	0.325
INC_8	54.1000	8.352	0.359	0.436	0.321
INC_9	54.4571	7.440	0.262	0.401	0.298
INC_10	54.0857	8.891	0.085	0.179	0.366
INC_11	54.4857	8.485	0.122	0.204	0.355
INC_14	54.6286	8.179	0.086	0.079	0.368
INC_17	54.0714	8.792	0.157	0.317	0.356
INC_18	56.0857	7.297	0.027	0.209	0.441
INC_19	54.6857	7.784	0.240	0.213	0.313

Table 2 shows that we can remove questions INC_5, and INC_18 and that

would increase the Cronbach’s alpha. Therefore, removal of the abovementioned questions would lead to an improvement in Cronbach’s alpha. We therefore consider removing these 2 variables in subsequent analysis.

Factor analysis of HIS Interoperability Constraints shall be analyzed.

Table 3 and **Table 4** show labels that were used in place of actual variable names to run the analysis. The analysis tables will display the labels in place of the actual variables.

Table 3. Variables key.

Interoperability Constraints			
Different Standard Protocols	INC_1	Leadership Management	INC_11
Lack of Training	INC_2	Broadband Costs	INC_12
ICT Infrastructure	INC_3	Security Privacy Integrity	INC_13
Financial Support	INC_4	Government Funding	INC_14
Policy Framework	INC_5	Engagement	INC_15
Socio-Demographic Variables	INC_6	Practitioner Skills	INC_16
Practitioner Cooperation	INC_7	Broadband Quality	INC_17
Practitioner Competences	INC_8	Cognitive Overload	INC_18
Existing Systems	INC_9	Institutional Architectures	INC_19
Facilities	INC_10		

Table 4. Total variance explained.

Component	Total Variance Explained								
	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
INC_1	2.06	17.164	17.164	2.06	17.164	17.164	1.659	13.826	13.826
INC_2	1.668	13.898	31.062	1.668	13.898	31.062	1.645	13.705	27.53
INC_3	1.365	11.378	42.44	1.365	11.378	42.44	1.424	11.868	39.398
INC_4	1.243	10.355	52.796	1.243	10.355	52.796	1.315	10.96	50.358
INC_5	1.063	8.859	61.655	1.063	8.859	61.655	1.264	10.536	60.895
INC_6	1.021	8.509	70.163	1.021	8.509	70.163	1.112	9.269	70.163
INC_7	0.887	7.392	77.555						
INC_8	0.827	6.894	84.449						
INC_9	0.598	4.985	89.435						
INC_10	0.509	4.246	93.681						
INC_11	0.389	3.246	96.926						
INC_12	0.369	3.074	100						

We observe 6 components whose Eigenvalue is at least 1 according to Kaiser's criterion. Therefore, the 19 variables/questions under the "Interoperability Constraints" theme seem to measure 6 underlying factors. This is because only our first 6 components have an Eigenvalue of at least 1. The other components having low quality scores are not assumed to represent real traits underlying our 19 variables/questions. Such components are considered "scree" as shown by the line chart below.

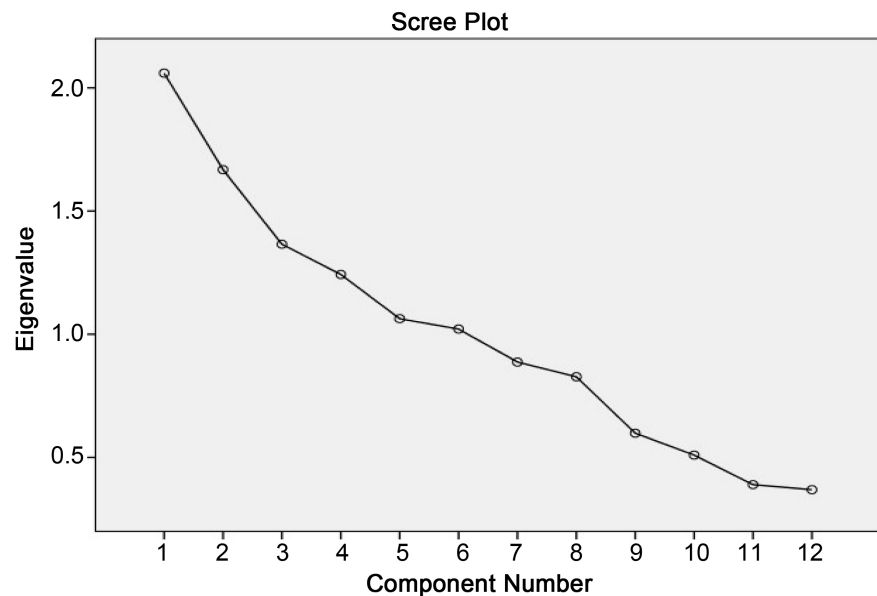


Figure 2. Scree plot on HIS interoperability constraints.

A scree plot visualizes the Eigenvalues (quality scores). Again, we see that the first 6 components have Eigenvalues over 1. We consider these "strong factors". After that, component 7 and onwards, the Eigenvalues start to drastically fall.

Our rotated component matrix (above) shows that our first component is measured by the following variables:

- INC_1-Different Standard Protocols
- INC_11-Leadership Management
- INC_17-Broadband Quality

We observe that these variables all relate to Protocol standards, leadership management and broadband quality. Therefore, we interpret component 1 as "Leadership management through broadband quality and protocol standards". This is the underlying trait measured by INC_1, INC_11 and INC_17.

Our rotated component matrix (**Table 5**) shows that our second component is measured by the following variables:

- INC_8-Practitioner Competences
- INC_19-Institutional Architectures

We observe that these variables all relate to Practitioner competence and institutional architectures. Therefore, we interpret component 2 as "Practitioner competence in institutional architectures". This is the underlying trait measured

by INC_8 and INC_19.

Table 5. Rotated matrix.

Rotated Component Matrix						
	Component					
	1	2	3	4	5	6
INC_1	0.799	0.024	-0.083	0.121	0.098	0.025
INC_17	0.774	-0.234	0.238	-0.164	-0.146	0.125
INC_11	0.543	0.459	-0.124	0.093	-0.044	-0.463
INC_19	-0.082	0.747	0.086	-0.065	0.236	0.122
INC_8	-0.046	0.591	0.452	-0.064	-0.126	0.180
INC_6	-0.065	0.004	0.806	0.187	0.039	-0.036
INC_9	0.205	0.346	0.677	-0.255	0.017	-0.077
INC_10	-0.030	0.000	-0.009	0.797	-0.114	-0.116
INC_18	0.244	-0.217	0.061	0.573	0.415	0.277
INC_2	-0.042	0.167	0.039	-0.025	0.860	-0.032
INC_4	-0.031	0.480	0.119	0.438	-0.482	0.011
INC_14	0.086	0.215	-0.078	-0.025	-0.021	0.858

Our rotated component matrix (above) shows that our third component is measured by the following variables:

- INC_6-Socio Demographic Variables
- INC_9-Existing Systems

We observe that these variables all relate to demographics and existing systems. Therefore, we interpret component 3 as “Demographics for existing systems”. This is the underlying trait measured by INC_6 and INC_9.

Our rotated component matrix (**Table 5**) shows that our fourth component is measured by the following variables:

- INC_18-Cognitive Overload
- INC_10-Facilities

We observe that these variables all relate to Cognitive overload and Facilities. Therefore, we interpret component 4 as “Cognitive overload from facilities”. This is the underlying trait measured by INC_18 and INC_10.

Our rotated component matrix (above) shows that our fifth component is measured by INC_2-Lack Of Training variable. Therefore, we interpret component 5 as “Lack of training”.

Our rotated component matrix (above) shows that our sixth component is measured by the – INC_14-Government Funding variable. Therefore, we interpret component 6 as “Government funding”.

After interpreting all components in a similar fashion, we arrived at the following descriptions:

Component 1 - “Leadership management through broadband quality and protocol standards”.

Component 2 - “Practitioner competence in institutional architectures”.

Component 3 - “Demographics for existing systems”.

Component 4 - “Cognitive overload from facilities”.

Component 5 - “Lack of training”.

Component 6 - “Government funding”.

Adding factor scores to our data.

We compute factor scores as means over variables measuring these underlying factors.

4.2. HIS Infrastructure Constraints

The Cronbach’s alpha for the “Infrastructure Constraints” theme, is $\alpha = 0.068$, which indicates a very low level of internal consistency for the scale in this specific theme as shown in **Table 6**.

Table 6. Reliability statistics.

Reliability Statistics		
Cronbach’s Alpha	Cronbach’s Alpha Based on Standardized Items	No of Items
0.068	–0.103	5

Table 7. Item total statistics.

Item-Total Statistics					
	Scale Mean If Item Deleted	Scale Variance If Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach’s Alpha If Item Deleted
IC_1	18.7606	1.328	–0.026	0.008	0.108
IC_3	18.7042	1.468	–0.090	0.020	0.130
IC_4	18.7183	1.491	–0.129	0.018	0.159
IC_7	19.3239	0.851	0.151	0.058	–0.167 ^a
IC_8	19.0845	0.736	0.122	0.067	–0.144 ^a

We can see that removal of questions IC_1, IC_3 and IC_4 would increase the Cronbach’s alpha (**Table 7**). Therefore, removal of the above-mentioned questions would lead to an improvement in Cronbach’s alpha. We therefore consider removing these 3 variables in subsequent Factor analysis.

Factor analysis results for HIS Infrastructure Constraints are then presented:

Table 8 and **Table 9** show labels that were used in place of actual variable names to run the analysis. The analysis tables will display the labels in place of the actual variables.

Table 8. Variables key.

HIS Infrastructure Constraints	
Standards and Protocols	IC_1
ICT Infrastructure	IC_2
Policy Framework	IC_3
Resources and Facilities	IC_4
Security Privacy and Integrity	IC_5
Broadband and Network Quality	IC_6
Institutional Architectures	IC_7
Existing Systems	IC_8

Table 9. Total variance explained.

Component	Total Variance Explained				
	Initial Eigenvalues			Extraction Sums of Squared Loadings	
	Total	% of Variance	Cumulative %	Total	% of Variance
1	1.222	61.118	61.118	1.222	61.118
2	0.778	38.882	100.000		

We observe that there is only 1 component whose Eigenvalue is at least 1 as shown in **Table 9**. Therefore, the 5 variables/questions under the “HIS Infrastructure constraints” theme seem to measure 1 underlying factor. This is because only our 1st component has an Eigenvalue of at least 1. The other components having low quality scores are not assumed to represent real traits underlying our 5 variables/questions. Such components are considered “scree” as shown by the line chart in **Figure 3**.

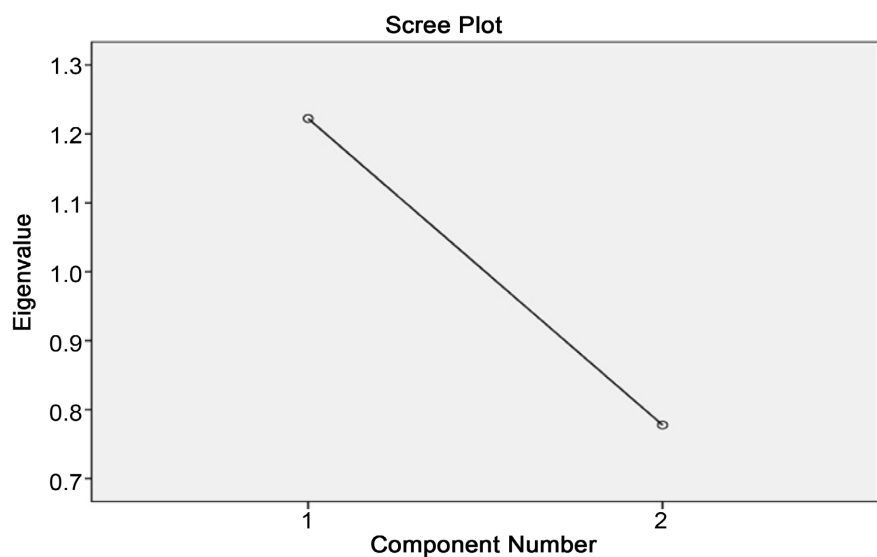


Figure 3. Scree plot on HIS infrastructure constraints.

A scree plot visualizes the Eigenvalues (quality scores). Again, we see that the first 5 components have Eigenvalues over 1. We consider these “strong factors”. After that, component 4 and onwards, the Eigenvalues drop off significantly. **Table 10** shows the Rotated component matrix for variables IC_8 and IC_7.

Table 10. Rotated component matrix.

Rotated Component Matrix	
	Component
	1
IC_8	0.782
IC_7	0.782

Our rotated component matrix (above) shows that our component is measured by the following variables:

- IC_7-Institutional Architectures
- IC_8-Existing Systems

We observe that these variables all relate to existing systems and institutional architectures. Therefore, we interpret component 1 as “Existing system architectures from institutions”. This is the underlying trait measured by IC_7 and IC_8.

Adding factor scores to our data.

We compute factor scores as means over variables measuring these underlying factors.

5. Discussion

The evaluation and addressing of interoperability constraints in health information systems are critical for enhancing healthcare delivery. This study aimed to assess the current state of interoperability, identify the key constraints, and explore strategies for addressing these constraints. The findings shed light on the challenges faced and highlight potential avenues for improvement [46].

The evaluation revealed several significant interoperability constraints in health information systems [47]. One of the prominent constraints identified was usability and skills limitations. Users, including healthcare professionals and IT staff, often encountered difficulties in effectively utilizing the systems due to inadequate training, complex user interfaces, and poor user experience design. These constraints hindered the efficient exchange and utilization of health data, impacting care coordination and decision-making processes [22] [38].

Infrastructure constraints and network connectivity emerged as another critical set of challenges. Insufficient hardware and software resources, outdated systems, and connectivity issues posed obstacles to seamless data transmission and accessibility [48]. These constraints hindered the timely and reliable exchange of health information, potentially leading to delays in care delivery and compro-

mised patient safety.

Interoperability standards and protocols constraints were also identified as a significant barrier to effective data exchange. Inconsistencies in data formats, lack of standardization, and non-compliance with interoperability standards created interoperability gaps between different systems. This hindered the integration and aggregation of data, limiting the ability to achieve a comprehensive view of patients' health information and impeding care coordination across healthcare settings [49].

To address these interoperability constraints and enhance healthcare delivery, several strategies can be implemented. First, improving usability and addressing skills constraints require prioritizing user-centered design principles and investing in comprehensive training programs for healthcare professionals and IT staff [28]. This will empower users to effectively navigate and utilize health information systems, leading to improved data exchange and informed decision-making.

Addressing infrastructure constraints and network connectivity requires investments in upgrading hardware and software infrastructure, ensuring reliable network connections, and implementing robust data storage and transmission mechanisms. This will facilitate seamless and secure data exchange, enabling healthcare providers to access and share patient information in a timely manner, regardless of location or system used [50].

Standardization of data formats and adherence to interoperability standards and protocols are crucial for overcoming interoperability constraints. Collaborative efforts among stakeholders, including healthcare organizations, technology vendors, and regulatory bodies, are essential to establish and enforce interoperability standards. This will ensure compatibility and consistency in data exchange, promoting seamless integration of health information across systems and facilitating care coordination [51].

6. Conclusion

In conclusion, the evaluation and addressing of interoperability constraints in health information systems play a vital role in advancing healthcare delivery. This study shed light on significant challenges such as usability and skills limitations, infrastructure constraints, and interoperability standards and protocols constraints. By prioritizing user-centered design, comprehensive training programs, and infrastructure upgrades, healthcare organizations can enhance usability, overcome connectivity issues, and establish reliable data exchange mechanisms. Adherence to interoperability standards and protocols, along with collaborative efforts among stakeholders, will ensure seamless integration of health information and promote effective care coordination. By addressing these constraints, healthcare delivery can be significantly improved, leading to better patient outcomes, enhanced decision-making processes, and improved overall quality of care. Continued research and investment in interoperability solutions are crucial for driving further advancements in healthcare delivery.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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