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The Role of Source Systems Strengthening in the Effective Interoperability of Digital Health Systems

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Abstract. Although electronic information systems (IS) that act as main sources of information in an ecosystem of digital systems are important in the success of IS interoperability, the conditions and challenges of source systems that affect IS interoperability have not received enough attention in the body of existing scientific knowledge. Using the System Theory, this paper relies on empirical evidence from two IS interoperability case studies to argue that the interoperability of electronic information systems can only succeed if due attention is paid to the individual systems that are involved in an IS interoperability project. Among other things, it was found that IS interoperability can only be achieved if the individual systems meet the requisite conditions, and that an environment surrounding a source system could substantially impact its ability to be interoperable with other systems.

Keywords: Information Systems Interoperability · Digital Health Systems · System Theory.

1 Introduction

The need to share data across electronic information systems (IS) has been a subject of professional and political engagements. This is especially because the sharing of data across electronic information systems enables decision makers to have a holistic contextual view of the situation on the ground, contrary to the skewed view of the situation, which is obtained when data from only some of the systems are used to make decisions. IS interoperability is also important in facilitating digital innovation in the medical field [11]. In Tanzania, for example, both the President and the Deputy Minister for Health have recently emphasised the need for electronic information systems in Tanzania to communicate with each other [7, 21]. For their part, IS professionals have gone as far as developing various policies and guidelines to facilitate the interoperability of electronic information systems. The Tanzania Digital Health Strategy 2019-2024 [20] is an example of several documents in the Tanzania IS interoperability policy framework. However, as it is argued in this work, these generic political and professional desires about IS interoperability tend to overlook various aspects of the individual systems that are responsible to make IS interoperability a success. In particular, the present work categorises the individual systems that are involved in an IS interoperability project as either source systems or destination systems, and emphasises the need to strengthen source systems if an IS interoperability project is to become a success. A source system, in the context

of this work, is one whose key role is to provide data to another system (hereafter referred to as a destination system). A destination system, on the other hand, is one that receives data from various source systems and facilitates, among other things, analysis, visualisation, and decision making based on the received data. Admittedly, because a broader notation of IS interoperability means that all interoperable systems can exchange data, it might sometimes be difficult to draw a line between source and destination systems in an interoperable network of information systems. However, in some contexts and as in the context of the study reported in the present paper, the individual systems in the network of interoperable systems could easily be categorised as either source or destination systems based on their specific roles in the network of information systems.

Moreover, studies on the interoperability of information systems have paid more attention to the assessment of the degree of interoperability between digital health systems [9,18], approaches for making the interoperability of digital health systems a success [1, 8, 10, 14], development and use of interoperability architectures and data sharing mediators and tools [15, 17, 19], and the standardisation of tools for collecting and reporting aggregate data [12, 13, 16]. However, little attention has been paid to various aspects of source systems that could be key in determining the success or failure of an IS interoperability project. Because of that, there is a paucity of evidence about aspects of source systems that could be key determinants of the success of interoperability of information systems. To contribute to the closing of this gap, the present study uses two case studies of integrating tertiary hospital information systems with the Tanzania national health data warehouse and integrating human resources for health information systems in Tanzania to study the role of source systems strengthening in the effective interoperability of digital health systems. Particularly, using the System Theory to conceptualise an interoperability project as a system of systems, the present study problematizes the key determinants of the success of IS interoperability projects, and seeks to provide answers to two key research questions:

- RQ1: What source system conditions are important for the success of interoperability of digital health systems?
- RQ2: What source system challenges could impact the effective interoperability of digital health systems, and how can they be addressed?

Theoretically, the present work contributes to the existing efforts to conceptualize an IS interoperability endeavour as an intricate system of systems [2, 4]. Empirically, the present work contributes practical insights that could guide practitioners to deliver successful IS interoperability projects.

2 Related Work

Studies related to the success of interoperability of digital health systems can be put into four groups. The first group has focused on the assessment of the degree of interoperability between digital health systems [9, 18]. For example, the work of Kang'a et al. [9] used a checklist developed based on the standards and guidelines for Electronic Medical Records (EMR) systems in Kenya to assess 17 EMR systems against various criteria, and found, among other things, a very low degree of interoperability among the assessed EMR systems. Similar findings were observed in the work of Shah et al. [18], in which low interoperability levels were found amongst the information systems used and maintained by the Local Health Departments in the United States. The second group of studies has focused on how to make interoperability of digital health systems a success [1,8,10,14]. In particular, both the studies by Kajirunga and Kalegele [8]

and Kobusinge [10] underscore the importance of interoperability considerations at the time of development of digital health systems, and emphasize the need to follow specific standards and guidelines at the time of development to ensure interoperable systems. The work of Mkayula et al. [14] used evidence from five referral hospitals in Tanzania to identify some of the key considerations for the successful interoperability of EMR systems maintained by different health facilities.

The third group of studies has focused on ensuring that destination systems receive data from source systems. Attention has especially been paid to the development and use of interoperability architectures and data sharing mediators and tools [15,17,19]. For example, Nsaghurwe et al. [15] reported the experiences of implementing a mediator that facilitates sharing of information across different digital health solutions in Tanzania. The work of Souza et al. [19] analysed the literature for different interoperability architectures and selected an architecture for use in creating interoperable Electronic Health Records (EHR) systems for public health organizations in Brazil.

The fourth group consists of studies that have mainly focused on source systems by standardising data collection tools for collecting aggregate data from health facilities to the national health data warehouse [12, 13]. However, little attention has been paid to the standardisation of data collection tools for non-aggregated data from the facilities. The present work complements the work of Mkayula et al. [14] by studying the actual EMR systems used by health facilities in all national, consultant and specialised hospitals in Tanzania. Because these hospitals tend to offer unique and specialised services, the systems used to collect data in these hospitals also tend to have unique and specialised functions and configurations. The present work sought to understand how systems that serve such unique and specialised contexts could be made ready for interoperability endeavours. As detailed in Section 4, the insights from national, consultant and specialised tertiary hospital EMR systems are also complemented by insights from various source systems that feed the national Human Resource for Health Information System, providing even richer insights on what needs to be done to make source systems ready for interoperability endeavours.

In addition, although Braa and Sahay [2] proposed the need to consider the process of making digital health systems interoperable as one that involves systems of systems in which users have great power to shape how the interoperability between systems should take place, there is little empirical evidence on the source systems' conditions and challenges that impact IS interoperability. In short, studies on the interoperability of information systems have paid little attention to a combination of socio-technical factors such as policy, legal, institutional, and technical factors that determine whether source systems can be successfully interoperable with destination systems.

3 Theoretical Lens: The System Theory

In the context of the System Theory [4], a system consists of a finite set of elements. Each element in a system has attributes, and there exist relations between different elements of a system. These elements, their attributes, and relations between elements form a structure that answers the *what* aspects of a system. Moreover, each of the individual elements of a system provides a unique contribution towards achieving the common objectives of a system, answering the *why* aspects of a system. The achievement of the objectives of a system is facilitated by the presence of several functions that are related within the structure of a system. This provides the answer to the *how* aspects of a system.

Further, the system boundary sets the borders for the system, providing an environment that helps to answer the questions on *in what* contexts of a system. Importantly, the environment of the system can influence the *evolution* of a system, redefining its objectives and borders. Fig. 1 summarises the concepts of a system in the context of a System Theory.

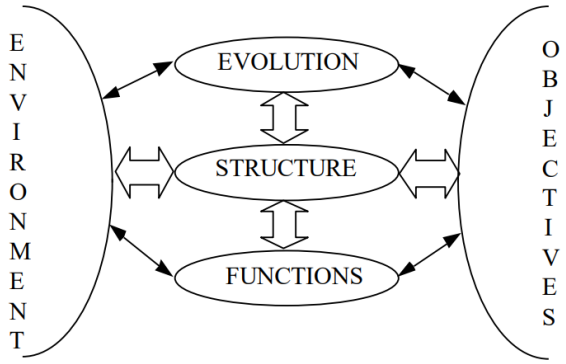

Fig. 1. System concepts in the context of System Theory (Source: Ducq et al. [4]).

However, complex systems put more emphasis on the idea of a system of systems [2,4], which is formed by a network of individual systems, each of which has its own environment, objectives, structure, functionalities, and evolution. Despite their uniqueness, the individual systems in a system of systems can be aligned together to serve common objectives, as shown in Fig. 2.

The System Theory facilitates high-level and low-level representation and study of a system. On the one hand, the high-level representation of a system (system of systems) enables an overall understanding of the system, taking the overall structure and objectives of a system into consideration. On the other hand, the low-level representation of a system enables the study and understanding of the practices and their controls in each of the individual sub-system in a system of systems. Because interoperability is among the key problems in a system of systems [4], using the System Theory enables us to study the context and challenges of interoperability at the low level (each system) and at the high level (system of systems), i.e., between various systems that form the interoperability network. Specifically, in the present study, it is argued that, because IS interoperability can be modelled as a system of systems [2, 4], the context and problems of the sub-systems play a key role in the success or failure of an IS interoperability project. In other words, the conditions that characterise the individual sub-systems play a critical role in the success of IS interoperability.

4 Method

The present study adopted a qualitative approach, in which exploratory case studies related to two interoperability projects were used to understand how source systems shape the fate of IS interoperability endeavours. An exploratory case study is important in answering questions such as the what and how of a studied context [22]. Embedded case studies were used, and the analysis was conducted at the organisational or system level.

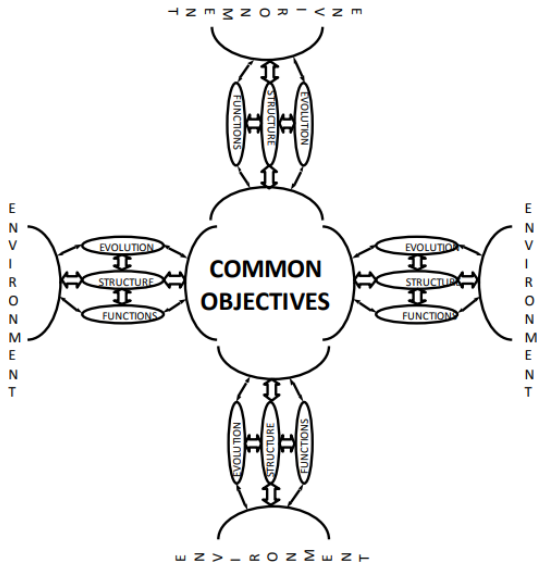

Fig. 2. A system of four systems with shared objectives (Source: Ducq et al. [4]).

4.1 Description of Cases

To ensure that various digital health solutions in the Ministry of Health (MoH) are interoperable, in the past four years, from 2019 to date, the MoH in Tanzania embarked on two big IS interoperability projects. The first IS interoperability project focused on ensuring that various electronic information systems used by all 13 national, specialised and consultant hospitals in Tanzania are interoperable with the national data warehouse (DHIS2) to better inform national health planning and decision making. This initiative aimed to ensure that the context of these tertiary hospitals is properly captured in the national data warehouse. Used by more than 60 countries across the world [3], the DHIS2 is currently used by all regions of Tanzania for reporting routine Health Management Information System (HMIS) data. A total of 13 hospital systems developed by 8 different vendors (some hospitals shared a systems vendor) were involved in the first IS interoperability project.

The second IS interoperability project focused on ensuring that all electronic systems that maintain data related to human resources for health—including pre-service data, in-service data, professional registration data, and professional development data—are interoperable with the Human Resource for Health Information System (HRHIS) [6], which facilitates analysis, visualisation, management and decision making on the national human resources for health agenda. A total of 9 source systems were involved in the second IS interoperability project. Of the nine source systems, two were systems for pre-service data (one maintained by the national regulator of university education and another one maintained by the national regulator of technical and vocational education and training), two systems were for in-service data (one for all workers in the Tanzania public sectors, the health sector included, and another one for health workers in the private sector in Tanzania), four systems were for four different health professionals registration councils in Tanzania, and one system was for record-

ing information about continuous professional development activities in which various health professionals in Tanzania were involved. Making these systems interoperable would enable, among other things, the computation of various indicators on human resources for health across the country; better planning, recruitment, deployment and management of human resources for health; and tracking of health professionals from university/college, to when they are employed, to when they are recognised as health professionals who are allowed to practice. The 22 source systems in the two interoperability projects presented avenues for studying various aspects of the source systems that could determine the success or failure of IS interoperability projects. Importantly, the 22 source systems and the 2 destination systems (DHIS2 and HRHIS) enable us to analyse each IS interoperability project from a global perspective (system of systems) and from a detailed perspective, focusing on the intricacies of each source system and how such intricacies impact the success of an is interoperability project. The author of the present paper was the participant observer in the two IS interoperability projects.

4.2 Data Collection

The data for the present study were collected through the project workshops, regular progress meetings (most of which were conducted weekly) for the two IS interoperability projects, in-situ interviews, and participant observation. Three workshops, each involving at least 26 stakeholders from the 13 tertiary hospitals and other MoH officials, were conducted for the DHIS2 interoperability project, while five workshops, each involving at least 18 source systems stakeholders and MoH officials were conducted for HRHIS interoperability project. To accommodate the needs and availability of various study participants, different approaches were used to conduct in-situ interviews of different stakeholders of the two IS interoperability projects. For the DHIS2 interoperability project, the in-situ interviews were semi-structured and involved stakeholders of the source systems in the 13 tertiary hospitals and were conducted either physically at the respective hospitals, through online calls, or through project workshops and progress meetings. One interview was conducted per tertiary hospital, forming a total of thirteen interviews. For the HRHIS interoperability project, the in-situ interviews were informal and were conducted during the project workshops and progress meetings. Specifically, through project workshops and progress meetings as well as the in-situ interviews of various project stakeholders, data were collected from software developers, business/system analysts, domain experts, focal persons of health management information systems, policy and decision makers from the Ministry of Health, vendors of source systems involved in the two IS interoperability projects, and donors.

The questions that were asked to participants during the workshops, progress meetings, and in-situ interviews mainly focused on gathering the following key information about each source system: system name; nature of data (aggregate or individual data) collected by a system; data collection and update frequencies; ability of a source system to generate aggregate data from individual data, if the system collected individual data; availability of report generation and data sharing Application Programming Interfaces (APIs); existence of an integration with any system, and how that integration was accomplished; whether the system would need further development before the integration with DHIS2 or HRHIS can take place; preferred mechanism for data exchange between the source and destination system (pulling or pushing); whether the system works offline or online; whether the source system encrypts the data before sharing it with other systems; mechanisms used by a source system to authenticate data

requests from other systems; any challenges that could hinder the establishment and sustainability of interoperability between a source system and other destination systems such as DHIS2 and HRHIS; and the suggestions of what could be done to make a source system effectively interoperable with destination systems like DHIS2 and HRHIS. To complement the data gathered through the workshops, progress meetings and in-situ interviews, various aspects of the source systems (including functionalities, nature of collected data, technologies used, and capabilities) were observed during the actual attempts to make the source systems interoperable with the destination systems, providing a better understanding of what was actually possible and what was particularly challenging with respect to making source systems effectively interoperable with the destination systems. The progress reports for the two projects and field notes were also used to complement insights gathered through other methods.

4.3 Data Analysis

Field data collection visits, workshops, regular project progress meetings, project progress reports, and conversations with various stakeholders were used to understand the aspects of source systems that affect the success of IS interoperability projects. To complement this understanding, a thorough analysis of workshop reports, in-situ interview transcripts, and field notes was conducted to search for themes about the technical conditions of source systems that determine the success of IS interoperability projects, as well as the IS interoperability challenges presented by source systems and how to navigate them.

5 Findings

The following are the findings on the source systems aspects that facilitate or hinder IS interoperability, and how to navigate the hindrances.

5.1 Source Systems Technical Conditions for the Success of IS Interoperability

It was found that most of the source systems for which the interoperability was successful were characterised by the following conditions.

Nature of Data Collected in a Source System: The nature of data collected by a source system–individual or aggregate data—was important in determining whether it could be interoperable with a destination system (DHIS2 or HRHIS). This was especially about the ability of a source system to produce data in a format acceptable to a destination system. As a destination system, the DHIS2 required aggregate data, while the HRHIS destination system required individual-level data. The EMR systems that were successfully integrated with the DHIS2 were not only capable of collecting individual-level data but were also capable of generating aggregate data in the HMIS reporting format required by the DHIS2. For example, as can be seen in the following quotes from the interview transcript, generating the aggregate data from JEEVA, the hospital system used by Muhimbili National Hospital, was relatively easy, because the developers of JEEVA had anticipated aggregate reports generation and interoperability requirements at the time of system development:

- *"JEEVA system is capable of generating aggregate information for data exchange from the individual information collected via the system"*
- *"Currently the JEEVA system collects patient data (individual data)"*

On the other hand, integration was not immediately possible for EMR systems that could not meet these conditions, and so developers of such source systems were required to generate aggregate reports from the individual data before integration was possible, and that was particularly challenging, because of the complexity of the database queries required to produce the required aggregate reports, given the diversity of data required on the HMIS reports. The situation was a bit different for the project dealing with the integration of source systems with the HRHIS, because individual records were acceptable in the HRHIS and any required aggregation could be done in the destination system. Therefore, the ability of a source system to produce data in a particular format is a key condition for a successful IS interoperability endeavour.

API Availability and Data Sharing Capabilities: The availability of a data sharing API (Application Programming Interface) was important in determining whether a source system could be interoperable with a destination system. Even more important was the ability of the source system's API to share data with other systems that are external to its organisation. In both the two IS interoperability projects, source systems that were successfully integrated with the destination systems were the ones for which the data sharing APIs existed before the interoperability endeavours, or their developers could easily develop data sharing APIs to respond to the IS interoperability dictates. The latter was mostly possible for source systems whose maintenance contracts allowed system vendors to develop APIs to facilitate IS interoperability endeavours. Of course, this also largely depended on the extensibility of the source systems, when necessary, to support interoperability with other systems. There were many source systems with maintenance contracts that did not have provisions that allowed vendors to adapt the source systems to make them interoperable with other systems. This stood in the way of interoperability between source and destination systems. In addition, the presence of prior integrations between a source system and other systems provided an important baseline and experience from which developers of a source system could easily pursue other integrations. Indeed, in the present study, it was relatively easier to integrate source systems with prior integrations compared to source systems that had no prior integrations. Thus, anticipating system interoperability at the time of development is likely to make a system more interoperable with other systems in the future.

Data Collection and or Update Frequency: The frequency of data collection and or update in a source system was also important in determining better ways to ensure the success and sustainability of interoperability between source and destination systems. For source systems in which data are collected on a daily or weekly basis, it was important for developers of source and destination systems to jointly agree on the frequency of data sharing from source to destination systems. Luckily, the e-government guidelines in Tanzania required a source system to propagate data updates to a destination system within 48 hours of data change in a source system ([5], Section 55). To prevent frequent communication between source and destination systems, which could make network and other system infrastructure unnecessarily busy, government guidelines and other context-specific dictates were used to determine the frequency with which source systems would share data with destination systems. Similarly, for source systems

in which data was collected on a weekly, monthly or so basis, agreements had to be made between stakeholders on when data would be shared from source to destination systems. However, some source systems had no clear data update frequencies, making some data collected through such systems somewhat unreliable, even if such systems were technically interoperable with the destination systems. For example, the Health Facility Register, which was used in the HRHIS interoperability project as a proxy system for data about employees in the private health sector, had data about employees that were not updated regularly, posing data unreliability challenges. To address these challenges, the Ministry had to devise a mechanism to ensure that employees' data in the HFR were updated regularly. That said, the clarity of source systems' data collection and sharing frequencies was important in determining the success of an IS interoperability project.

Preferred Data Sharing, Encryption, and Authentication Mechanisms: The mode with which source systems preferred to share data with destination systems was important in determining the success of an IS interoperability project. Two main options were available: push, in which data could only be available in a destination system if the source system initiated the data sharing process, and pull, in which a destination system could go to the source system to fetch data from it. While most source systems preferred a push mechanism for reasons related to security and control of what data was shared, some source systems that had no strict security constraints were willing to allow a pull approach that allowed destination systems to determine when and how to obtain data from the source systems. Although it gives more control to source systems, the push approach threatens data sharing sustainability, particularly in the absence of clear motivations for continuous data sharing by source systems. That is why a pull mechanism is preferable in contexts when the destination system considers itself to have anything to lose if source systems do not share data. Additionally, the source systems' use of data encryption and authentication mechanisms that are compatible with destination systems made data sharing easy, facilitating the success of an IS interoperability endeavour.

Ability of a Source System to Work Online: Source systems that worked on the internet were more likely to share data with destination systems than source systems that worked offline. Moreover, integration between source and destination systems was more likely if source systems were web-based applications than when they were standalone applications. Thus, web-based source systems are more likely to be interoperable with other systems than their standalone counterparts.

5.2 Source System Interoperability Challenges and How to Navigate Them

This section presents the social-technical challenges of source systems that hindered the success of IS interoperability projects, and how to navigate them.

Heterogeneity of Systems: The presence of heterogeneous systems developed by different technologies, with different capabilities, and covering different health portfolios hindered the smooth execution of interoperability endeavours. Although developed differently, some source systems collected similar data and had similar functionalities. Examples of such systems included the system for

other professional registration councils and the systems for the Medical Council of Tanganyika, the Tanzania Nursing and Midwifery Council, and the Pharmacy Council of Tanganyika, which, in essence, were all responsible for the registration and management of health professionals. Thus, there were a lot of source systems and data to be carefully analysed before interoperability could take place. Prior harmonisation of the many heterogeneous source systems could help reduce the number of source systems and associated intricacies to be considered before IS interoperability can become a success. However, because the politics on the ground meant that each of the heterogeneous source systems had to be considered as independent and deserving of special consideration, the number of diverse source systems to be considered and their unique features increased significantly, complicating the whole process of making source systems interoperable with destination systems.

Multiplicity of Vendors: Although similar in important ways, most source systems had been developed by different vendors. The tertiary hospital systems-DHIS2 interoperability project involved 13 systems that had been developed by 8 different vendors (some vendors developed systems for more than one hospital), while the HRHIS interoperability project involved 9 source systems that had been developed by 9 different vendors. All these vendors had diverse and competing interests and systems development skills that had to be reconciled before IS interoperability could be a success. For example, some source system vendors had difficulties in developing data sharing APIs, while others struggled to generate aggregate data from individual data for sharing with the destination systems. Other source system vendors preferred a push mechanism to data sharing, even if it meant reasonable data sharing delays. In general, it is easier to deal with harmonised and well-streamlined vendors than diverse and sometimes conflicting vendors with systems that largely serve duplicate objectives.

Data Sharing Policies: The absence of (and sometimes unclear) data sharing policies by organisations owning source the systems delayed or sometimes prevented the IS interoperability projects. This was especially observed in the HRHIS interoperability project, whereby in two public organisations that owned some key source systems, the signing of data sharing agreements and the actual sharing of data from the source systems to the destination system took almost two years instead of a few months that had been envisioned earlier. In the tertiary hospitals-DHIS2 integration project, there was one tertiary hospital that was too secretive with their data and system to the extent that the actual integration of their system with the DHIS2 never started, despite the months of concerted efforts to tick their bureaucratic boxes.

Support Contracts: Most of the source systems that were involved in the two interoperability projects were developed by vendors who also had contracts to support users, maintain and evolve the systems after deployment. The existence and nature of the maintenance contracts were important in determining whether the source systems could be made to be interoperable with the destination systems. For example, in the tertiary hospitals-DHIS2 interoperability project, there was a vendor who had supplied a system to three different tertiary hospitals and the maintenance contracts for that vendor at all three hospitals had expired at the time of pursuing the tertiary hospitals-DHIS2 interoperability project. This made the integration of the DHIS2 with the systems at the three tertiary hospitals experience reasonable delays, since all the three tertiary hospitals had no system developers with the capacities to develop the systems and

so the involvement of vendors was necessary during the interoperability endeavours. In another tertiary hospital, the maintenance contract was in place, but making their system interoperable with the DHIS2 was considered to be a new feature that was not covered under the existing maintenance contract. Thus, the presence and coverage of contracts to maintain the source systems hindered the success of an IS interoperability endeavour. To navigate this challenge, the period and coverage of maintenance contracts for source systems should be properly negotiated.

Missing Data and Inability to Track Information Across Systems: All source systems missed important data that were required in destination systems after systems integration. Each source system had some required data and missed other required data. For example, in the HRHIS interoperability project, there was no source system whose development goal was to capture and manage data for health professionals working in the private sector in Tanzania. So, the electronic Health Facility Register (HFR) was used as a proxy system for obtaining data for health workers in the private sector. However, since HFR was essentially not an HR system, the data it contained about health professionals in the private sector had a lot of gaps and were not updated on regular intervals. In such circumstances, strengthening of the HFR was an important and necessary condition for the success of the HRHIS interoperability endeavour. Importantly, the missing data in the source systems made it impossible to track individuals across different systems. Different source systems used different unique identifiers, making it impossible to track individual health professionals across pre-service, in-service and professional registration systems. For example, because of this challenge of missing or invalid data in source systems, developers of the destination system in the HRHIS interoperability project were at some point requested by the client and the donor to check the validity of the data received from the source systems before storing them in the destination system and to inform a source system in case an invalid data was detected. As can be seen in the following quote from the minutes of one of the progress meetings of the HRHIS interoperability project, doing so complicated the work of developers of the destination system, who, ideally, should have limited ability to detect invalid data collected by the source systems.

"The challenges that we face is that sometimes we are pushed to implement new requirements that are not written even in the test cases, for example validating data from the source systems and sending notifications on invalid data. This is not present in the written requirements and test cases..."

After further discussions and consultations, it was agreed in later project meetings and workshops that checking for data validity should mainly be done by the source systems, to minimize the amount of data processing and the potential for data misrepresentation in the destination systems. A similar situation was observed in the source systems that were involved in the tertiary hospitals-DHIS2 interoperability project. Most hospital systems had some missing data, hindering the completeness of the data required in the DHIS2.

6 Discussion

This study sought to understand the technical conditions of source systems that are important for the success of IS interoperability projects, and the socio-technical challenges of source systems that hinder the success of IS interoperability projects and how to navigate them. Based on the System Theory [4], in general, the findings of the present study indicate that the achievement of the

overall objective of the system of systems, which is to make destination systems interoperable with source systems, can only be possible if the individual systems in the system of systems meet the requisite conditions. All elements (individual systems), their attributes (e.g., conditions of the individual systems that influence or hinder IS interoperability), and the relationships between the individual systems, which together form the structure of the overall system of systems, must be carefully analysed and adapted accordingly for an IS interoperability project to succeed. This should include a careful examination of the objectives of the individual source systems in relation to the overall objective of making the source systems interoperable with a destination system. Any mismatch in the objectives of source and destination systems might hamper the interoperability endeavours. For example, the Health Facility Register (HFR) system was originally developed to facilitate the registration of health facilities in Tanzania; however, due to the absence of an electronic system dedicated to collecting and managing data about health professionals working in the private sector in Tanzania, HFR was used as a proxy source system for health professionals in the private sector in Tanzania. Nevertheless, because facilitating HR functions was not the main objective of the HFR, necessary improvements in terms of the data it collects, and system functionalities were required before HFR could properly service the main HRHIS interoperability objective. This, in turn, hindered the attainment of an interoperable HRHIS that can reliably account for all health professionals working in the private sector in Tanzania.

Moreover, an alignment is required between the functions of the overall interoperable system and the individual source systems in the overall system. For example, because the DHIS2 mainly stores routine aggregate data, the ability of the source systems to generate aggregate data and share them with the DHIS2 via an API was important in the success or failure of an IS interoperability project. Most of the tertiary hospital systems for which the interoperability with the DHIS2 has not succeeded so far lacked system functions that could service the needs of the DHIS2. As can be seen in Section 5, the opposite is also true: source hospital systems that were successfully integrated with the DHIS2 had specific functions that generated and shared the data in accordance with the dictates of the DHIS2. A similar situation was also observed for the HRHIS interoperability project. For example, while tracking a health professional from pre-service, to in-service, to professional registration and development was among the envisaged key functions of the overall interoperable HRHIS, the source systems lacked the functions and data to make that a possibility, hindering the implementation of the tracking functions in the overall interoperable HRHIS. All other sociotechnical conditions that surrounded the source systems, including policy, legal, institutional and infrastructure aspects constitute the environment that surround the source systems that were involved in the IS interoperability projects. As detailed in the findings, an environment surrounding a source system could substantially impact its ability to be interoperable with other systems. For example, the timely signing of data sharing agreements, the existence of maintenance contracts between the organisations that own the source systems and the vendors of source systems, and the alignment of interests between vendors and other stakeholders of source systems provided enabling environments for the success of the IS interoperability projects. On the contrary, source systems that were surrounded by an environment that lacked these ingredients were hardly interoperable with the destination systems. Thus, careful analysis and improvement of the environment that surrounds the source systems is key to the success of an IS interoperability endeavour.

Finally, the findings of the present study also point to the fact that the evolution of the source systems might be a necessary condition for the success of an

IS interoperability endeavour. This evolution might be viewed as an important initiative to strengthen the source systems before they can be ready for interoperability. The strengthening might focus on ensuring that the source systems capture all important data and have all important functionalities and features that are required to make it interoperable with the target destination systems. In short, strengthening the source systems is an important and sometimes necessary condition for the success of an IS interoperability project. Therefore, paying attention to other aspects while downplaying the strengthening of source systems is a problematic condition that could lead to the failure of an IS interoperability project.

7 Conclusion and Recommendations

Although source systems are important in the success of IS interoperability projects, the conditions and challenges of source systems that affect IS interoperability have not received enough attention in the body of existing scientific knowledge. The present study set out to understand the important technical conditions that make source systems amenable to interoperability, as well as the challenges of source systems that hinder IS interoperability projects and how to navigate them. Among other things, the findings of this study point to the fact that the success of IS interoperability projects strongly depends on the conditions of the source systems. Thus, the present study recommends that thorough assessment and, if necessary, strengthening, of source systems, should be a key consideration if any IS interoperability project is to become a success.

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