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Review

Review

Clinical information system (CIS) implementation in developing countries: requirements, success factors, and recommendations

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ABSTRACT

Objective: Clinical Information System (CIS) usage can reduce healthcare costs over time, improve the quality of medical care and safety, and enhance clinical efficiency. However, CIS implementation in developing countries poses additional, different challenges from the developed countries. Therefore, this research aimed to systematically review the literature, gathering and integrating research findings on Success Factors (SFs) in CIS implementation for developing countries. This helps to integrate past knowledge and develop a set of recommendations, presented as a framework, for implementing CIS in developing countries.

Materials and Methods: A systematic literature review was conducted, followed by qualitative data analysis on the published articles related to requirements and SF for CIS implementation. Eighty-three articles met the inclusion criteria and were included in the data analysis. Thematic analysis and cross-case analysis were applied to identify and categorize the requirements and SF for CIS implementation in developing countries.

Results: Six major requirement categories were identified including project management, financial resources, government involvement and support, human resources, organizational, and technical requirements. Subcategories related to SF are classified under each major requirement. A set of recommendations is provided, presented in a framework, based on the project management lifecycle approach.

Conclusion: The proposed framework could support CIS implementations in developing countries while enhancing their rate of success. Future studies should focus on identifying barriers to CIS implementation in developing countries. The country-specific empirical studies should also be conducted based on this research's findings to match the local context.

Key words: clinical information systems, developing countries, implementation, CIS, requirements, critical success factors, low-resource settings, digital health

INTRODUCTION

Many low- and middle-income countries struggle to deliver comprehensive healthcare services because of budget limitations, poor policy, or technical and human resources inadequacy.[1] To address these issues and improve care quality, structural reforms and increasing the number of healthcare workers have been implemented.[2] However, these have not completely addressed the issues, and major challenges remain in fulfilling the population's healthcare requirements. Coronavirus disease 2019 (COVID-190 caused unprecedented

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disruption to the healthcare system in general, and in low- and middle-income countries in particular, this has aggravated the situation.[3] Clinical information system (CIS) implementations are perceived as solutions to address the increasing issues of demand and supply,[4] and especially after COVID-19, healthcare has been witnessing the benefits of digital health tools and solutions.[5]

CIS is a computer-supported system for collecting, storing, managing, and making important clinical information available for the healthcare delivery process.[6] In this research, CIS encompasses electronic information systems used in healthcare, ranging from improving quality of health and patient safety to enhancing clinical efficiency. A specific type of CIS, Electronic Medical Record (EMR), is used extensively in Europe and the United States.[4,7] Other subcomponent technologies in CIS, such as order entry systems and decision support systems, are also playing an important role in reducing medical errors, improving the efficiency and quality of healthcare.[7] CIS supports medical staff by providing easy and systematic access to patients' data.[2]

However, CIS implementation is challenging with relatively high uncertainty of success, even for developed countries.[7] Despite several attempts on adopting CIS to facilitate medical information recording, only a few have successfully implemented.[8,9] Many IT projects have failed in healthcare,[10] with CIS failure rates of up to 70%.[11] This situation is more complex in developing countries because of resource constraints.

To minimize CIS failure and reduce financial loss, especially in developing countries, it is essential to raise the success rates of implementations.[12] This can be achieved through continuous knowledge enhancement,[13] careful requirement gathering, analysis, understanding, and considering the fundamental "success or failure" causes in CIS implementation.[14]

This research attempts to gather and integrate the available knowledge on CIS implementation requirements and Success Factors (SFs). By comparing and contrasting the findings for both developing and developed countries, this study could have important contributions to broadening the understanding of the requirements and SF for CIS implementation in developing countries. The integrated knowledge was classified into requirements and their related SF and presented as considerations in a framework specific to developing countries.

CIS helps physicians with analyzing patients' conditions, choosing treatment options, and monitoring wellness activities.[6] CIS scope can be limited to a single area, eg, ICU Information System (IS), or can encompass all aspects of the clinical care process, such as EMR and laboratory IS.[6,15] The core components of CIS are categorized as Electronic Healthcare Records (EHR), clinical decision support,[6] computerized provider order entry, digital sources of medical evidence and decision-support tools,[16] speciality systems such as oncology, and ancillary ISs (eg, pharmacy, laboratory, or radiology ISs). CIS also can be accessed for physicians' and researchers' training or research.[6]

CIS implementation is expensive and complex with extreme disruption to the conventional workflow. To optimize CIS benefits, careful planning and harmonizing with the healthcare service delivery process is necessary. Successful implementation involves a long continuous process, from planning, designing, and piloting to intermittent use, changing for acceptance, and incorporating into the routine process.[17] CIS success is a dynamic concept ranging from finishing projects within the estimated budget and time, meeting the target outcomes, or getting users' satisfaction.[18] This success can be measured using evaluation models[19–22] or traditional project management (PM) concepts, such as delivering CIS within the approved budget, timeframe, and promised quality and benefits of CIS.[23] User satisfaction, perceived usefulness, and quality are also associated with IS success.[24,25]

Various strategies for successful CIS implementations have been suggested[26,27]; some of them can be generalized irrespective of the settings, while others might be very specific depending on the cultural factors, computer skills, and organizational and user requirements.[28] Different studies have been conducted to identify the SF to reduce CIS implementation failure which investigated the contributed SF from different perspectives, such as user acceptance,[29] user expectations and CIS functionality,[30] or the differences in implementation in 2 countries.[31] Some studies have identified and categorized SF for different types of IS used in various healthcare disciplines. Research was conducted for oncology-related CIS,[32] while another study identified the SFs and barriers to the implementation of CIS in an integrated care setting.[33] Ten factors were proposed for the successful implementation of EHR (a type of CIS),[34] while another study identified 26 critical SFs for EHR adoption.[35] These studies have different sample sizes of 16[36] and 35 articles.[37]

These examples demonstrate a lack of consistency and comprehensiveness in CIS implementation requirements and SF. Furthermore, most research studies considered CIS in developed countries, with a limited focus on developing countries.[38–41] The majority of the studies about CIS implementation were conducted in North America (69.45%) followed by Europe (19.45%).[42] As implementation requirements for developing countries is different from that of developed countries,[7,43,44] different sets of requirements and SFs might contribute to the CIS's successful implementation. Therefore, this study aims to integrate the available knowledge to address specific requirements of developing counties, and extract knowledge to apply in developing countries. This can be presented as considerations in a framework specific to developing countries.

MATERIALS AND METHODS

A Systematic Literature Review (SLR) was conducted, followed by a qualitative thematic and cross-case analysis of selected published literature. SLR was selected to aggregate and synthesize past information on the topic to provide a comprehensive presentation of the available knowledge.[45]

Given the multi-disciplinary nature of the research, 5 databases were selected: PubMed, ScienceDirect, IEEEXplore, Scopus, and Google Scholar databases. To gather articles from these databases, the keywords (Supplementary Appendix SA) and their possible synonyms and acronyms were included to construct search strings (Supplementary Appendix SB). The publication date was set to include the published articles between 2000 and 2020. This gave us 254 articles. After removing 72 duplicates and adding 2 more relevant articles from the literature review process, 184 articles remained for the full-text assessment. Abstracts and full-text were skimmed based on the inclusion/exclusion criteria (Supplementary Appendix SC) that excluded further 101 articles. A total of 83 articles were included in the qualitative analysis. The process of systematic article selection followed Staples and Niazi's SLR guidlines[46] and presented using the PRISMA diagram[47] (Figure 1).

Using 83 articles, a dataset in NVivo[48] was created for thematic and cross-case analyses. An in-depth reading of articles was performed to extract data related to requirements, their SF, and barriers to CIS implementation. The extracted data were grouped into relevant themes/categories which were created based on deductive and inductive reasoning.[49,50] The deductive method was used to

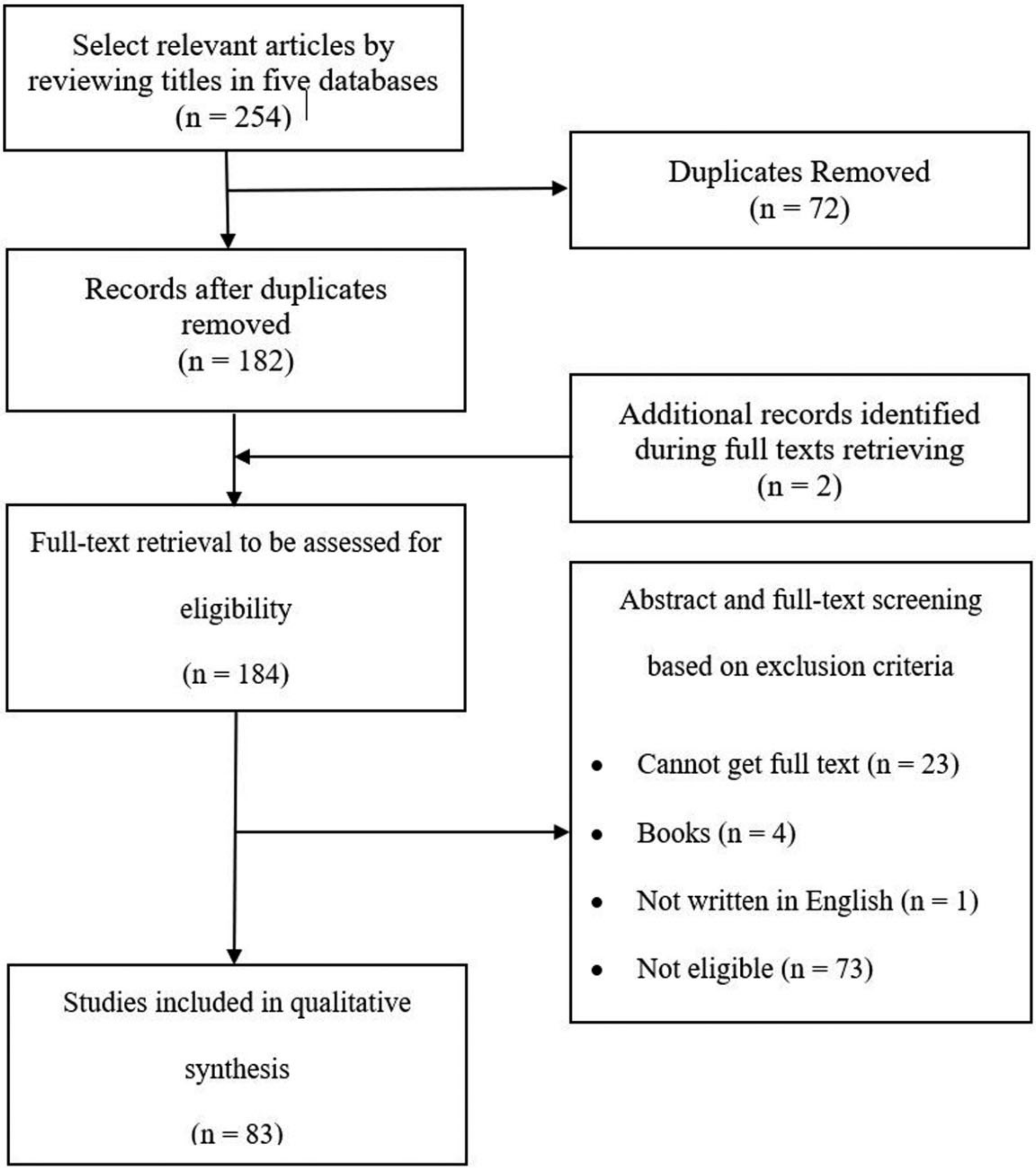

Figure 1. PRISMA diagram.

pre-define the main categories based on our research objectives, including developing countries, developed countries and general. The general category is added as some articles did not specify whether the research was for developing or developed countries.

For the rest of the analysis, the inductive method was used to explore all the possible requirements and their SF. The combined reasoning method allowed us to classify the requirements and SF for developing countries and developed countries. It also helped in the identification of the emerging SF and requirements in the latter stage with the inductive method.[51]

After thematic analysis, the stacking method was used to organize and compare[52] the requirements and SF of 3 cases: (1) developing countries, (2) general, and (3) developed countries. The stacking technique is a method of displaying a series of cases in a meta-matrix by fields of interest.[52] Each case was organized in a comparable frame that enabled a systematic visualization and contrasting of all cases together at the same time. As case-2 data represented both developing and developed countries, case-2 was recognized as a general (common) case. Data from case-1 and case-3 were moved and merged into case-2 if there were similar requirements and SF (Figure 2). The data unique to case-1 or case-3 were marked separately during the merge, to keep track of requirements and SF for developing countries and developed countries. After stacking the 3 cases, a comprehensive framework was created for requirements and their SF for implementing CIS in both developing and developed countries.

RESULTS

Most articles in this study were from high-income countries (60.2%), followed by low- and middle-income countries (20.5%)

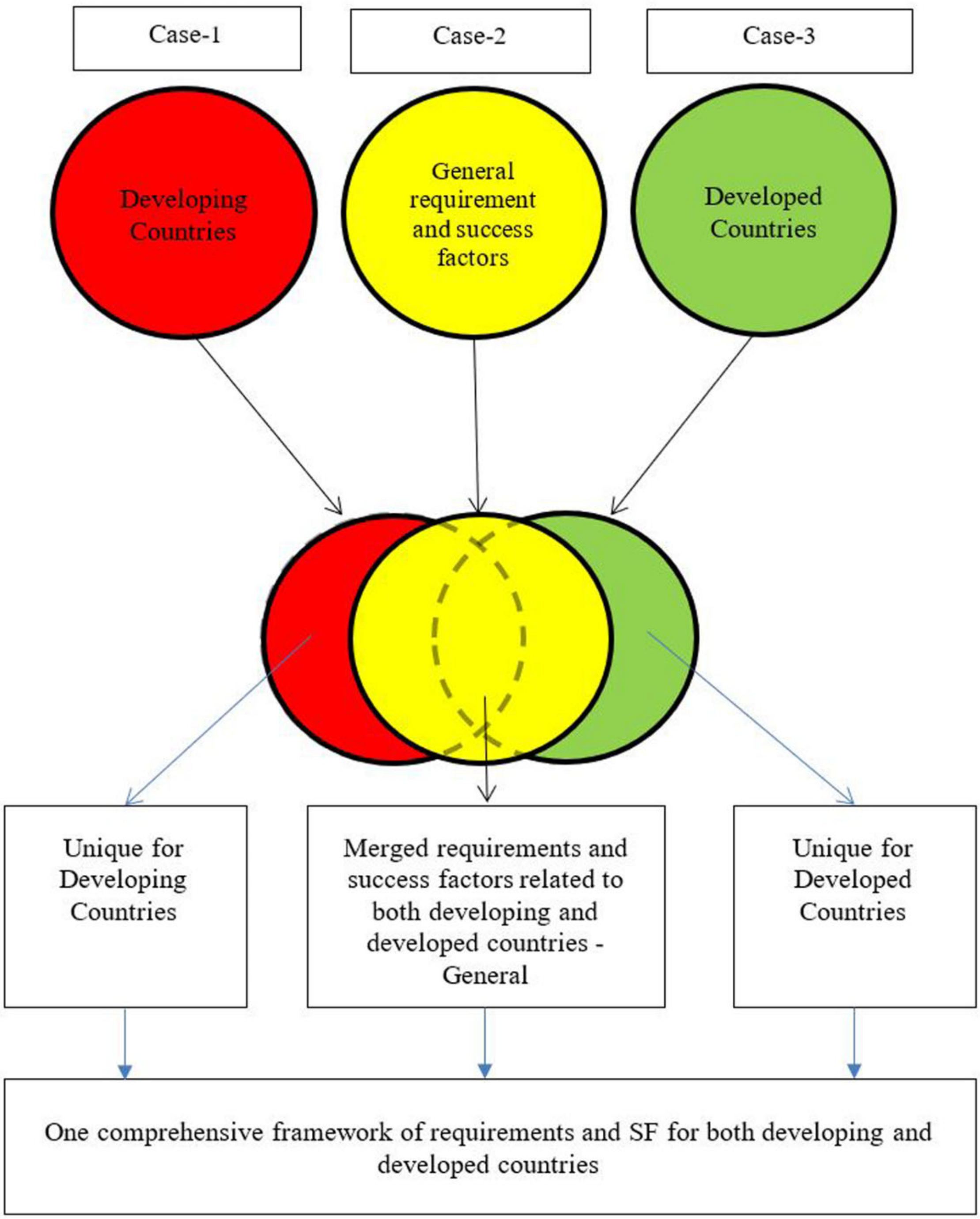

Figure 2. Cross-case analysis: stacking method.

and not specified (19.3%). Supplementary Appendices SD and SE provide the detailed characteristics of these articles.

We identify a set of requirements necessary for CIS's successful implementation, which helps to define a benchmark for successful CIS implementation. Our analysis reveals 6 major requirements with their related sub-categories and SFs (Figure 3).

For each requirement, its SF(s) were identified. The SF is defined as a vital element in addressing the identified requirements and the overall CIS project's success.[26] For example, change management (CM) is a part of PM,[53,54] and "feedback-dialogue" is identified as its SF.[44] Similarly, in "Communication", "trust and reliability" is recognized as effective communication SF.[55] See Supplementary Appendix SF for the list of requirements and SFs.

Project management

PM is "the application of knowledge, skills, tools, and techniques to project activities to meet the project requirements".[56] PM is a strong factor in CIS's successful implementation,[57] which is classified into subcategories (Table 1).

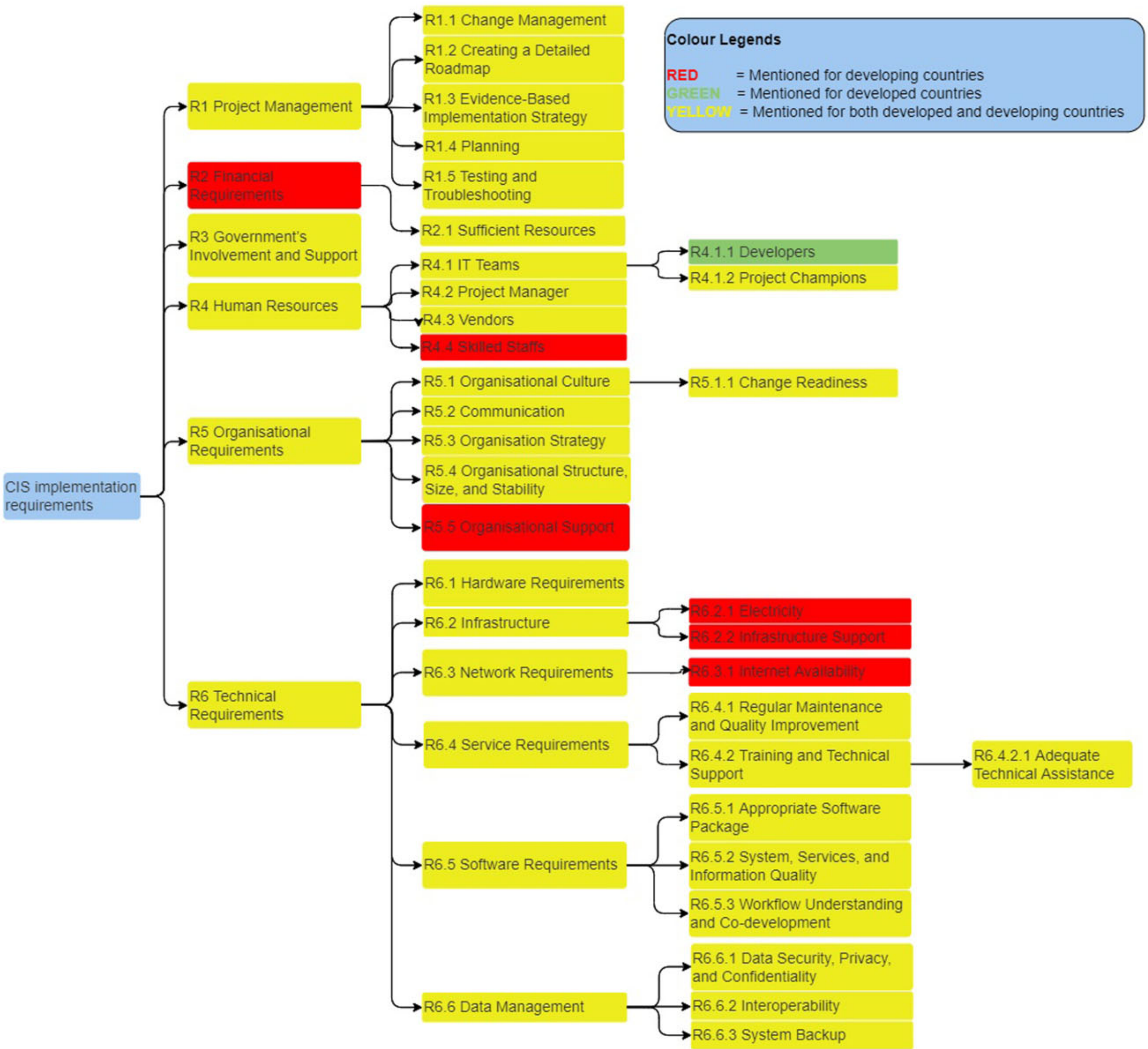

Figure 3. CIS implementation requirements.

Financial resources requirement

Financial resources (FR) are the foundation of projects. Although FR cannot guarantee projects' success,[2,58,59] neglecting them is a significant barrier to the CIS's success.[60] A significant positive relationship between FR and CIS success has been reported.[61,62] FR is the major requirement mentioned in the studies related to developing countries (see Table 2 for related SFs).

Government involvement and support

National and local governments' support directly affects the success of CIS implementations, despite healthcare organization management having no control over the government policy.[53] Political factors such as a change in government, their willingness for CIS investment, policy, flexible bureaucracy, and quality control tools can influence the success of CIS.[61] Government organizations may establish requirements which aim to increase effectiveness and efficiency, such as patient safety, quality improvement, and patient rights. The CIS should be designed to fulfil the requirements set by the government to get support from the government.[53] The related SFs of this category are shown in Table 3.

Human resources

Human resources (HR) plays a critical role in CIS implementation success.[2,26] Our results indicate among all HR requirements (Table 4), "project champions" has a major contribution to CIS implementation success.[4,42,63] To raise success, having clinical champions with IT and PM knowledge as project leaders is a "*must*".[64–66] Clinical champions can represent end-users, and by providing training and technical support, help to overcome clinician resistance, bridge gaps between different groups of stakeholders, and resolve communication issues between IT and clinical teams.[40,66–69]

Organizational requirement

Organization requirements (Table 5) should be considered for CIS implementation.[17] Compared with other requirements, they have

Table 1. PM requirements and number of articles included

Requirements	No. of articles (developing countries)	No. of articles (developed countries)	No. of articles (not specified)	Total no. of articles	% of total articles ($n = 3$)
R1 Project management	0	0	0	0	0.00
R1.1 Change management	13	4	5	22	26.51
R1.2 Creating a detailed roadmap	3	1	2	6	7.23
R1.3 Evidence-based implementation strategy	2	0	1	3	3.61
R1.4 Planning	10	2	2	14	16.87
R1.5 Testing and troubleshooting	0	3	4	7	8.43

Table 2. FR, SF, and number of articles included

Requirements and success factors	No. of articles (developing countries)	No. of articles (developed countries)	No. of articles (not specified)	Total no. of articles	% of total articles ($n = 3$)
R2 Financial resources requirements	0	3	0	3	3.61
Adequate funding	6	2	3	11	13.25
Budgeting methods	0	1	0	1	1.20
Resource allocation	4	0	3	7	8.43
R2.1 Sufficient resources	8	0	2	10	12.05
Long-term commitment of resources	2	0	0	2	2.41
Annual budget for IT	2	0	0	2	2.41
Sufficient budget for continued operation and maintenance	0	1	0	1	1.20

Table 3. Government's involvement and support requirements, SF and number of articles included

Requirements and success factors	No. of articles (developing countries)	No. of articles (developed countries)	No. of articles (not specified)	Total no. of articles	% of total articles ($n = 3$)
R3 Government's involvement and support	4	4	3	11	13.25
Allocating separate budgets for CIS projects	0	2	0	2	2.41
Developing and implementing legislation for data ownership, privacy and security	0	1	0	1	1.20
Industry support	1	0	0	1	1.20
Government policy	0	2	0	2	2.41
Political willingness	4	1	2	7	8.43
Incentives for implementers	0	0	1	1	1.20
Interest-free loan	1	0	0	1	1.20
Strategic IT planning	0	2	0	2	2.41
Investigate and invest in alternative infrastructure facilities	0	1	0	1	1.20

Table 4. HR requirements, SF, and number of articles included

Requirements and success factors	No. of articles (developing countries)	No. of articles (developed countries)	No. of articles (not specified)	Total no. of articles	% of total articles ($n = 3$)
R4 Human resources requirements	1	3	2	6	7.23
R4.1 IT teams	1	0	0	1	1.20
R4.1.1 Developers	1	0	0	1	1.20
R4.1.2 Project champions	27	2	9	38	45.78
R4.2 Project manager	6	0	2	8	9.64%
R4.3 Vendors	0	0	0	0	0.00%
R4.4 Skilled staff	0	5	0	5	6.02%

limited influence on the success of CIS implementation.[70] Nevertheless, they are interrelated with other SFs with "communication" being one of the most cited requirements. Having different communication approaches at different levels is critical for the successful implementation of CIS.[17] Constant communication, project updates, and clear information flow among all stakeholders facilitate individual commitment and reduce resistance to change. Communication is the foundation that holds teams together.[71] "Knowledge transfer" and "trust & reliability" are the associated SFs for achieving effective communication. Other studies describe "Trust & reliability" as SF not limited to proper communication but also for the CIS implementation.[55,72]

Technical requirement

Technical requirements (Table 6) have less influence on the success of CIS than human factors such as healthcare professionals' attitudes and involvement.[70,73] However, they are closely linked with HR and organizational requirements.[17] Therefore, due to the high interdependencies, technical requirements are as important as other requirements.

Software package

Instead of in-house development, selecting from the available CIS products and their customization is recommended. To minimize customizations, selecting appropriate software and system architecture that fits the desired organization's CIS is essential.[18,71] Cost, user-friendliness, interoperability, and vendor are among important factors for CIS selection. A well-defined selection process and criteria can increase implementation success.[44,74,75] "Ease of Use" is associated with supporting the clinical workflow[37] so users use the system with a minimum time.[76,77] The presence of clearly written processes can help the users with effective usage and time-saving while preventing workarounds.[78]

Open-source systems are popular for CIS implementation in developing countries.[7,79–81] They have lower installation costs and availability of source codes makes customization possible.[7] For system sustainability and gaining ownership,[2] upskilling is necessary. Starting with relatively comprehensive open-source software with a large network of supporting communities such as the OpenMRS platform can facilitate adoption.[82] Open-source software and customization bring huge advantages to resource-constrained situations that are considered SF.[2]

Designing the system

The system also should be customized to match the requirements of the organization and stakeholders. Understanding the workflow and co-development of the system with IT, clinicians, and project teams become essential in this step. To increase user acceptance, CIS should be designed to fit the clinical work tasks and information flows, and match the paper-based system and electronic system.[17,42,53,83] The customization process could increase costs and times, error susceptibility, and limit the advantage of updates and upgrades.[71,84] The Workflow Analysis Task Force, including clinical staff, can be created to seek and choose an approach best fit for the practice.[65,85]

Identifying CIS data types is another crucial task. This identification can be undertaken using end-user requirement analysis, and the clinical staff.[18] The clinicians should actively participate and identify data types and their definitive source for each data item.[17,64] Thus, standard data quality can be achieved with the approval of the end-users which motivates them to become involved in the data entry process.[77] Having quality data can also enhance decision-making quality, and promote long-term advantages such as enabling the

Table 5. Organizational requirements and number of articles included

Requirements	No. of articles (developing countries)	No. of articles (developed countries)	No. of articles (not specified)	Total no. of articles	% of total articles ($n=3$)
R5 Organizational requirement	1	4	1	6	7.23%
R5.1 Organizational culture	6	2	3	11	13.25%
R5.1.1 Change readiness	0	0	1	1	1.20%
R5.2 Communication	12	5	6	23	27.71
R5.3 Organization strategy	7	1	2	10	12.05
R5.4 Organizational structure, size, and stability	2	3	1	6	7.23
R5.5 Organizational support	0	2	1	3	3.61

Table 6. Technical requirements and number of articles included

Requirements	No. of articles (developing countries)	No. of articles (developed countries)	No. of articles (not specified)	Total no. of articles	% of total articles ($n=3$)
R6 Technical requirement	2	3	1	6	7.23
R6.1 Hardware requirements	0	0	0	0	0.00
R6.2 Infrastructure requirements	0	0	0	0	0.00
R6.2.1 Electricity	0	2	0	2	2.41
R6.2.2 Infrastructure support	0	2	0	2	2.41
R6.3 Network requirements	0	0	0	0	0.00
R6.3.1 Internet availability	0	3	0	3	3.61
R6.4 Service Requirements	0	1	0	1	1.20
R6.4.1 Regular maintenance and quality improvement	5	0	2	7	8.43
R6.4.2 Training and technical support	28	11	11	50	60.24
R6.4.2.1 Adequate technical assistance	6	4	4	14	16.87
R6.5 Software requirements	0	0	0	0	0.00
R6.5.1 Appropriate software package	9	6	3	18	21.69
R6.5.2 System, services and information quality	3	4	4	11	13.25
R6.5.3 Workflow understanding and co-development	17	2	8	27	32.53
R6.6 Data management	0	0	0	2	2.41
R6.6.1 Data security, privacy and confidentiality	6	5	5	16	19.28
R6.6.2 Data quality and interoperability	3	1	6	19	22.89
R6.6.3 System backup	1	0	1	2	2.41

discovery of new treatments, improving current treatments, and shortening drug development duration.[35,83]

Data management

Implementing CIS comes with several workflows, information collection, and storage changes including converting paper records into the CIS system in developing countries.[18,44,71] A data standardization process is necessary to improve data quality and where required interoperability.[35,86] While ensuring interoperability can be achieved following standards, a broader long collaboration between end-users and data managers is essential to ensure their consistency.[83] All stakeholders' involvement, especially end-users, is crucial for CIS implementation.[17,53,87] A skilled data manager can monitor data quality regularly using survey tools and feedback meetings.[7]

Data security, privacy, and confidentiality in healthcare are of prime importance. Healthcare data contain sensitive and personal information, when breached, it can have negative consequences on patients, the worst case being the patient's identity theft.[88] Therefore, the government's role is critical to establish legislation for confidentiality, data privacy, and security.[89] Additionally, valuable medical data needs to be backed up with a disaster recovery plan to prevent the loss of data from various conditions such as external attacks, or any natural disasters.[66,90]

DISCUSSION

We reviewed and integrated the available knowledge for successful CIS implementations in developing countries. The findings were presented as a list of requirements, SFs, and recommendations; "*Training and Technical Support*" having the highest contribution. This implies long-term plans for local workforce training considerably improves CIS success rates in developing countries. This training addresses other important implementation requirements including "*project management*" and "*human resources*", and their SFs including "*effective project management*", "*change management*", and "*project champions*".

Supplementary Appendix SF provides a detailed comparison of requirements and SFs for developing and developed countries. Although the identified requirements and SFs can be considered for a general CIS project implementation, our results suggest that priority should be given to the list, unique to the developing countries (Figure 4).

Based on Figure 4 and a comparative analysis of the requirements in Supplementary Appendix SF, a framework is proposed, structured based on the PM lifecycle.[91] This framework (Figure 5) is customized and identified different tasks and activities in project lifecycle phases . Based on the significant role of CM in CIS success, we proposed this area as a separate phase. This framework also considers the Principles for Digital Development (PFDD).[92]

CIS project life cycle

Project initiation and planning

To guide the implementation, manage expectations, and allocate roles and responsibilities, project planning is required.[93] It starts with a clear business case with measurable objectives[54] and covers long-term plans with clear long-term perspectives, and endurance.[36,67,81] For realistic implementation plans, project initiation is crucial. For example, rigorous research before CIS implementation is suggested[94] to identify best practices, prerequisites, and minimum hardware and software requirements.

Strong organizational vision and strategy[17] should clearly articulated and clinically focused planned activities[40,95] to achieve organizational goals following the overall strategy.[86] Proper understanding of the organization's IT ecosystem and workflow,[53] and scalable or expandable design with sustainability elements are also described as important factors in both this study and PFDD.[92] The presence of context-relevant e-health implementation strategies and frameworks[89] is an important SF.

Organizational and technical readiness assessments help the project team to have realistic planning for implementation. Almost 50% of the SFs under technical requirements, unique for developing countries, are infrastructure related. Electricity and Internet availability are obvious requirements mentioned by several researchers.[2,61,82,96] Investment in alternative infrastructure facilities (eg, electricity) as a part of strategic IT planning is recommended, such as alternative power sources, solar, diesel-fuelled electricity generators, or small-scale hydropower generators for remote areas.[89]

Some network and server requirements can be addressed using cloud technology[97] with attention to the existing hardware capabilities within the organization. Software compatibility is another consideration which has been impacted by rapid technological advancement, the turnover rate of hardware such as PCs and mobile devices. Regular hardware upgrades and software updates improve overall efficiency.[7,61]

In many developing countries, healthcare services are largely provided by government-funded public systems,[98] while other funds (eg, donor funds or private fees) should seek the government's approval. This makes the success of CIS implementations directly dependent on government involvement and support.[53] Government supports, involvement, and actions are also required in other areas such as developing legislation for data ownership, privacy, and security.[89] These can only be fulfilled at the government level. Infrastructure requirements (eg, electricity and network) also heavily depend on the government's support. The existence of government policy for CIS implementation and political willingness to invest in CIS is crucial for its success.[14,26,36] Therefore, healthcare organizations should seek governments' support and interest in the CIS by initiating policy briefings.

To maximize the success of CIS implementation, allocating a dedicated budget from governments is recommended to support the capital investment for CIS implementation, continuing operation, and maintenance.[89,96] Furthermore, allocating annual budget for IT is suggested[99] due to the huge potential limitations in technology and infrastructure requirements in low-resource settings. To keep governments' support, setting small wins or milestones, with measurable goals, is recommended to monitor the return on investments. These goals can be set based on CIS financial and non-financial benefits such as improved patient care and outcomes, cost savings, or increased efficiency.[18,40,64] These could facilitate access to donor funding as a financial source for healthcare in developing countries. Criteria to secure these funds are having a clear link between the fund and the results,[100,101] which might be challenging in CIS projects, as these projects normally have mid or long-term benefits.

Project CM

CM is critical in dealing with required organizational, technical and process changes, and human factors to obtain the desired benefits of

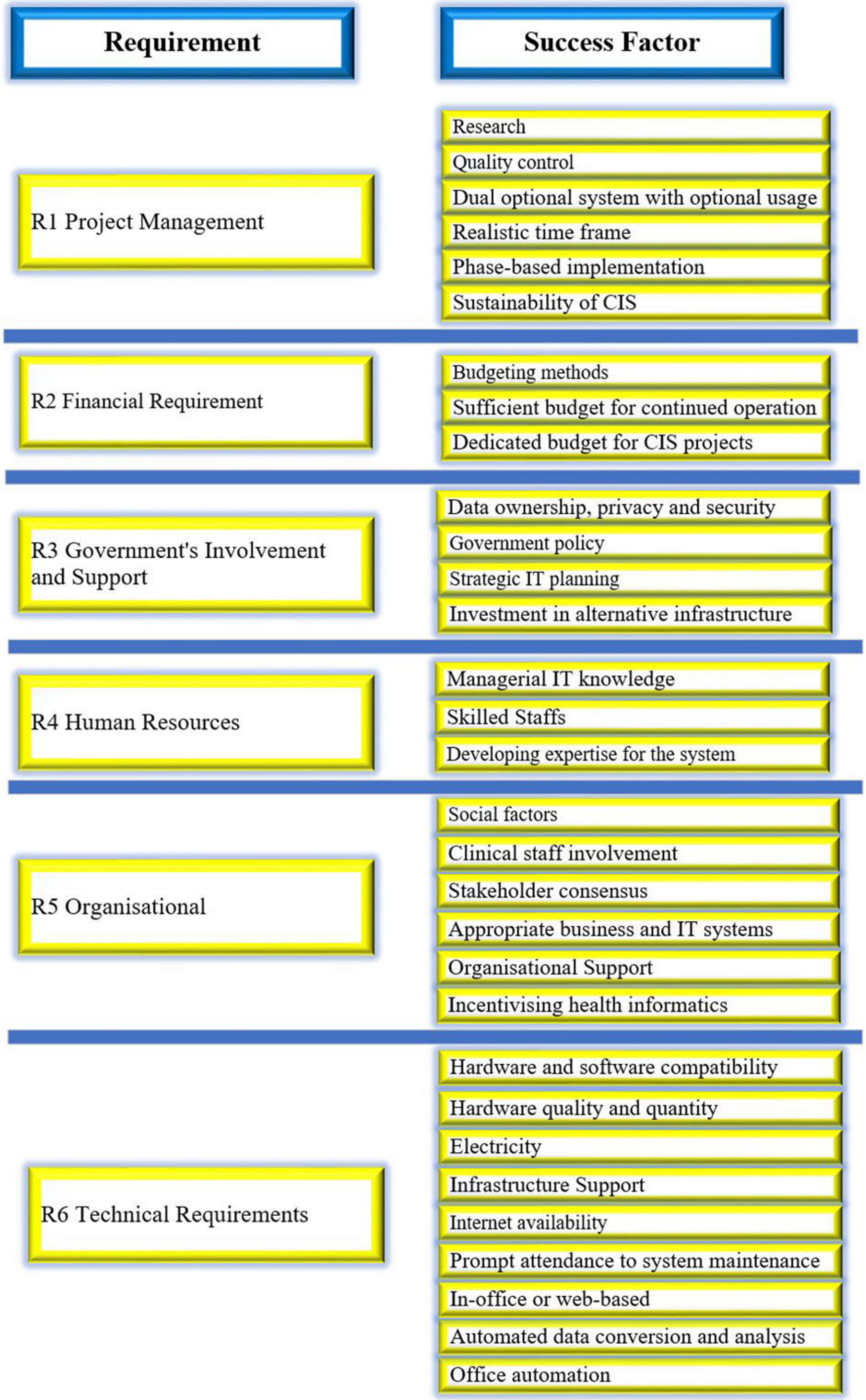

Figure 4. Requirements and SF related to developing countries.

CIS implementation.[102] CM is also interrelated to other requirements and SFs and should be approached from all stakeholders' perspectives to be successful. For a successful implementation, preparing the foundation for change through some activities has been suggested including creating demand for CIS, selling the benefits of CIS, promoting successful efforts, setting regulations and incentives, making customer-focused services, and achieving quick wins for stakeholders.[69,78,99,103,104]

Users should be prepared for changes and be introduced to the new systems and their related benefits. This reduces resistance to change, improves the attitudes toward the system, and includes activities such as stakeholders' involvement, feedback sessions, and providing support groups to alleviate the effects of change and resistance.[105] At this stage is important to have more organizations manage these activities and systematically apply knowledge and use tools, models, and strategies for CM.

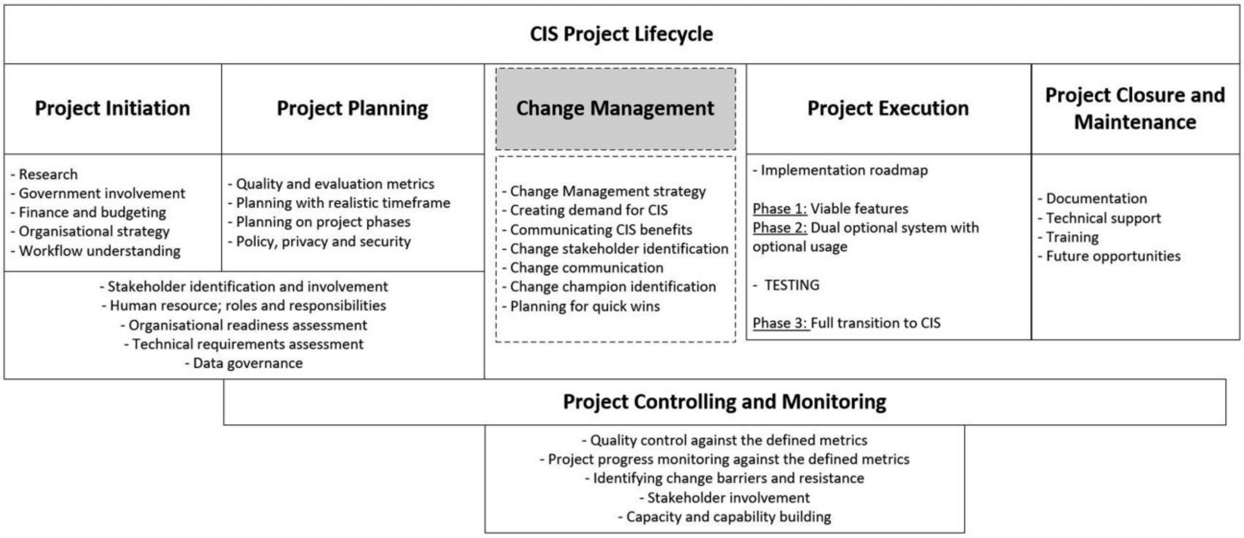

Figure 5. CIS project lifecycle for developing countries.

Promoting the benefits of CIS, facilitating knowledge sharing among the peer groups, and involving the stakeholders in the system design and development reduce change resistance.[61,96] Our findings also reveal that "*involvement of all stakeholders*", "*top management support*" besides building a "*multidisciplinary team*" are other important criteria for consideration. These also have a close relationship with "*workflow understanding and co-development*", which all require effective communication. Staff commitments and efforts are also important for these radical changes or digital transformations in operational and clinical processes.[106] Similarly, PFDD suggested involving users in all stages of implementation starting with developing clear, common vision and goals in "Design with the users".[92]

Project execution

Appropriate planning and CM strategy could improve project implementation and execution, especially in healthcare.[107] For an implementation strategy, first, a manageable CIS scope is required[35] followed by realistic expectations and time-frame.[18,30] A detailed roadmap for CIS implementation is needed[40] including policies and procedures, legal and ethical requirements, clear responsibilities and reporting hierarchy, and new practice standards or routines.[36,64,66,108]

CIS projects can be implemented as a rapid expansion of the system, common in developed countries, or phased-based, for developing countries. To avoid the co-existence of old and new systems, phased-based implementation is suggested[109–111] including timelines and milestones for each phase.[74] Therefore, following agile implementation approaches could increase the rate of success. As agile methods are based on iterative processes with high stakeholders' involvement in implementation, the satisfaction rate and consequently stakeholders' attitudes and commitment toward CIS could be enhanced.[36,57,112] Governments can also assign professional bodies to explore the most suitable implementation strategies in the local context.[89] Therefore the following general phases, set in collaboration with users and stakeholders, are suggested:[92]

Phase-1: The minimum viable CIS and its features can be implemented. This simple system design and release are suggested by Standing and Cripps[31] for developing countries. With this phase, the project team could involve clinical staff as suggested by Leatt et al[66] and Narattharaksa et al[96] and get their feedback as users. The feedback could be addressed in the iterations of CIS development which makes the final product more appealing to users, although using others' experiences and pilot-testing are helpful in the planning process.[64,65]

Phase-2: Dual-option system with optional usage could be made available for users.[109] Allowing the optional usage of the system is found to be an SF in developing countries,[81,109] therefore the studies recommended a step-by-step transition from one system to another, in developing countries. This phase also allows less technically savvy staff and respects everyone's rhythm[111] to start the transition. Also, testing the system in working condition could help developers to identify any potential hardware and software compatibility.

Phase-3: After all system testing and considering the factors such as usability[33] and accessibility[35] of the system for users, we can have the full transition to CIS.

Project controlling and monitoring

Quality control and progress monitoring against the defined criteria in the planning stage should start and end with the project. The quality control aspect needs to be given enough attention so that the sustainability of the system is guaranteed.[2,26,81] This sustainability is critical for the system's future expansion and the incorporation of additional features, comparable with PFDD "Design for Scale".

Identifying change resistance should be considered from the early stages. This makes people and organizations ready for new CIS implementation and transition. Accordingly, PFDD emphasizes sharing success and failure experiences, expert opinions, and open resources[92] to build good long-term relationships with involved stakeholders.

Having enough "*skilled staff*" can facilitate implementation and address SF in the technical requirement of "*prompt attendance to system maintenance*".[61] Capacity and capability building and continued staff upskilling have considerable effects on CIS projects' success. This can be deducted by referring to different requirements and SFs including skilled staff such as project and clinical champions,[40,42] software developers,[31] and managers with IT knowledge.[61] This assures enough expertise to operate the system[61] are available.

The inclusion of health informaticians is increasingly prevalent for CIS success.[65] Health informaticians and their involvement are necessary in each implementation phase. These professionals can act as project champions and participate in providing training and technical support for users. Therefore, governments should focus on enabling the development of health informaticians and creating proper career pathways within the countries to develop a culture of working with data.[89]

Project closure

Training and education are required to cover CIS logic and concepts, its features, and hands-on training to managers and employees. This helps users to understand the reasons for CIS implementation and gain necessary skills to use the system through functional training.[18] Hands-on training for medical staff is more effective than classroom-style; as technical education and behavioral changes are required for user acceptance. Effective ways of training include shadowing the clinicians and answering the questions spontaneously.[113]

Providing adequate technical support to the users is an important requirement that influences the success of CIS.[66] The users should have enough on-site technical and training support to address their issues quickly, especially in the first week of implementation.[85] Clinicians are under pressure during patient care and require immediate support with CIS to keep up with the lag of time.[18] Developing a plan is required to assist clinicians at the point of care besides training, especially within the first few weeks of implementation.[40]

Training and supports are important for improving user acceptance to facilitate the success of CIS. CM deals with user behavior, stakeholders' perspectives, and organizational culture, while training and support deal with the users' requirements. Training and support, if provided in line with the CM approaches, may have a synergistic effect on increasing the chances of CIS implementation success.

Considering CIS sustainability would help at this stage to identify future features for the system (eg, automatic data conversion and analysis[114] or office automation). Including automation in the software system is also a good approach to convincing the stakeholders.[26,94,114]

PFDD focuses mainly on 2 major themes: (1) users' involvement, feedback, and collaboration; and (2) proper documentation of the project plan, implementation process, and challenges faced. Some areas in PFDD match with our findings, including "Design with users", "Understand the existing ecosystem", "Design for scale", "Build for sustainability", "Data-driven", and "Privacy & security". The other areas that can also further improve the CIS's success include: "Use open standards"; "open-data, open-source, and open innovation"; "Reuse and improve"; and "Be collaborative".[92]

CONCLUSION

The findings of this research offer a comprehensive set of requirements, SF, and recommendations in a PM lifecycle approach for CIS implementation in developing countries. Moreover, the results are contrasted with the PFDD to gain additional insights. The results of this research can be helpful to guide CIS projects in developing countries with limited resources, and the success of CIS is critical.

This study was limited to investigating the requirements and SF for CIS implementation. Future studies should focus on identifying barriers to CIS implementation in developing countries and match with the requirements and SF to gain better insights and improve the chance of CIS success. It is recommended that projects in developing countries include the findings of this research based on the user attitude, infrastructure conditions, budget availability, political willingness, and many other factors to assess readiness for a project and key requirements for success. Future research and evaluation studies in developing countries could be designed to measure the effect of the requirements and SF from this research on the success of CIS implementation.

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AUTHOR CONTRIBUTIONS

SYYT was responsible for data collection and data analysis. These tasks undertook under SMs' supervision and guidance. SM proposed the CIS Implementation framework and contributed to the research method, reflection on research results, and data interpretation. SYYT prepared the first draft of the research report and the manuscript. Both documents were reviewed and commented on and their clarities were enhanced by SM. Both authors agreed on the final revision.

SUPPLEMENTARY MATERIAL

Supplementary material is available at *Journal of the American Medical Informatics Association* online.

CONFLICT OF INTEREST STATEMENT

None declared.

DATA AVAILABILITY

Data are available in a public, open access repository. The data underlying this article are available in the article and in Supplementary Appendices SD and SF.

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