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System Requirements Analysis for Picture Archiving and Communication System Deployment in Iraq

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ABSTRACT

Picture Archiving and Communication Systems (PACS) are essential components of digital radiology because they support the storage, retrieval, display, protection, and exchange of medical images across hospital departments. In resource-limited environments, PACS adoption is affected by several system-related factors. These factors include usability and data security, retrieval speed, interoperability, and infrastructure readiness, as well as adequate user training; This study provides an engineering analysis of the design requirements for PACS-based medical imaging systems in Iraqi healthcare institutions. A quantitative questionnaire was distributed to 60 healthcare professionals and technical stakeholders to identify workflow limitations, PACS awareness, functional requirements, non-functional requirements, and adoption barriers. The results showed limited practical exposure to PACS among respondents. The main problems during the workflow were the delayed access to patient data and reports, human errors during data entry, high update costs, and weak integration between hospital systems. The main requirements identified from these findings include fast retrieval, easy maintenance, scalability, reliability, privacy protection, and workflow integration. The findings were mapped into engineering design implications to support the development of a locally adapted PACS platform. The study indicates that the successful implementation of the PACS system in Iraqi healthcare institutions can be achieved through a phased deployment approach, a standardized architecture, user training, security controls, and interoperability planning, as essential conditions.

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1. INTRODUCTION

Medical imaging departments require more than acquisition and display devices. These departments depend on an information infrastructure that connects imaging modalities, databases, patient records, viewing workstations, reporting tools, communication networks, and access control systems. Picture Archiving and Communication Systems (PACS) support the storage, retrieval, transmission, display, and management of medical images and related reports [1]. Because medical images are distributed between many devices and healthcare organizations, standards-based interoperability—particularly through Digital Imaging and Communications in Medicine (DICOM)—is essential to the PACS system's reliable operation [2]. Therefore, a PACS-based system should not be treated as a simple image storage application; a medical imaging system built on the PACS should be designed as an integrated engineering system. Patient registration, study management, image uploading, image indexing, image retrieval, diagnosis viewing, reporting, user authentication, and integration with hospital information systems should all be supported. Before implementation, these functions should be translated into precise functional and non-functional requirements from a requirements engineering perspective [3]. The system's long-term value is additionally determined by its responsiveness, scalability, data security, privacy, interoperability, reliability, and maintainability.

PACS deployment in Iraq faces additional practical challenges. The digital infrastructure, technical support, staff training, interoperability readiness, and available budget of healthcare organizations differ. Organizational, technical, and resource-related barriers can impact the adoption of digital health, according to a previous study on healthcare information system adoption in Iraq's Kurdistan Region. [4].

A recent study of the PACS standards for Iraqi hospitals highlighted the need for locally customized medical imaging solutions and found that healthcare professionals had limited practical experience with this system [5].
Previous studies have shown that PACS adoption is affected by user acceptance, perceived usability, ease of use, organizational readiness, training, cost, security, and interoperability [6-9].
This study addresses the requirements engineering stage of designing a PACS-based medical imaging system for Iraqi healthcare institutions. It examines medical and technical questionnaire responses from participants about functional and non-functional requirements, mapping these responses to adoption barriers and their effects on engineering design. The goal is to provide a basic and practical environment for establishing a PACS system that is easy to use. secure, privacy-preserving, scalable, interoperable with other systems, and flexible enough to meet the workflow requirements.
The study's contributions can be summarized as follows:

1- This study identifies the obstacles to adopting PACS in Iraqi healthcare institutions from a systems engineering perspective.
2- It classifies user expectations into functional and non-functional requirements for PACS system design.
3- Maps reported workflow problems to engineering design implications, including retrieval performance, data-entry control, interoperability, security, usability, reliability, and maintainability.
4- Proposes practical recommendations for phased PACS deployment in resource-constrained hospital environments.

2. RELATED WORKS

The use of PACS, medical image sharing, healthcare information systems, interoperability standards, and implementation difficulties in hospital settings have all been covered in earlier research. The reviewed works are presented in chronological order to show how PACS research has moved from adoption and knowledge barriers toward interoperability, workflow integration, and locally adapted system requirements.

Paré and Trudel (2007) [6] knowledge barriers influencing the adoption and use of the PACS, in hospitals were studied in previous research. The study showed that PACS implementation requires good change management, organizational learning, stakeholder participation, and efficient knowledge sharing. This is relevant to the present study since PACS adoption in Iraqi healthcare facilities may be restricted by low awareness and insufficient training.

Aldosari (2012) [7] This study analyzed PACS user acceptance in the radiology department of a Saudi Arabian hospital and how medical staff interacted with the system. The study describes that the system improved communication among staff, Image retrieval, and workflow in the department. Also, the study highlighted the challenges they face, when using the PACS system in hospitals. So they need to receive deep training to learn to deal with the system. This study confirms the importance of user acceptance when using the PACS system in hospitals.

Goodarzi et al. (2016) [10] This study measured the acceptance of the PACS system in the emergency department. The study found that users' tendency to accept the system was affected by perceived usefulness, ease of use, system quality, and organizational readiness. That is, referring to the use and implementation of PACS is both an organizational and a technical problem.

Mohamed (2017) [4] public hospitals in the Kurdistan Region of Iraq, with a focus on the high cost, lack of standardized implementation strategies, and a lack of experience and skills, which were the main challenges. This study shows that resource, technical and organizational limitations can affect the implementation of such systems in Iraq.

Abbas and Singh (2019) [8] addressed PACS deployment challenges at a public healthcare institution from the vendor perspective. The most challenges that they faced were in infrastructure limitations, image storage requirements, system maturity, and implementation environments, because it relates infrastructure to PACS deployment challenges.

Eid et al. (2022) [9] This study is about exchanging medical images in the Middle East. Researchers confirm the importance of interoperability, integration between imaging systems and hospital workflows, and structured image exchange. This shows why, in PACS design, interoperability must be considered a basic engineering requirement.

Andriole (2023) [11] This study addressed the development of PACS systems from early digital image access systems to modern digital imaging workflow-focused platforms. The study showed that the PACS system has developed from just image archiving to become a more complete infrastructure for workflow support and is integrated with (Artificial Intelligence) AI technology. This helped the methodology of the current study, which considers PACS as an engineering platform rather than a simple image repository..

Larobina (2023) [12] studied the DICOM standard thirty-year history and explained how it has made medical

imaging data interchange, storage, and communication and interoperability of medical imaging information easier. This work is very important because PACS architecture requires structured exchange mechanisms and interoperability with medical imaging standards, particularly when systems from different departments or suppliers need to communicate.

By treating these challenges as an engineering requirements problem and converting user-reported constraints into functional and non-functional system design requirements, this study promotes this approach. Implementing a PACS requires more than just image storage capacity, according to reviewed studies. User acceptance, training, infrastructure preparation, interoperability, standards compliance, security, and ease of maintenance are all important factors. However, most previous studies have addressed these challenges separately. Some of these studies focused on user acceptance, while others focused on regional image exchange, public sector implementation barriers, or DICOM-based interoperability. This study addresses this gap by converting obstacles to PACS implementation in Iraqi healthcare institutions into functional requirements, non-functional requirements, and engineering design responses for a locally suitable PACS-based medical imaging system. Table 1 summarizes the related studies and their importance highlighted, to the present engineering requirements analysis.

Table 1: Related Works

Ref. and Year	Objective	Main findings	Relevance to this study
"Knowledge Barriers to PACS Adoption and Implementation in Hospitals" [6]	To examine knowledge barriers in PACS adoption and implementation.	Successful implementation required knowledge sharing, staff involvement, and organizational learning.	Supports the need for training, awareness, and implementation planning.
"User Acceptance of a Picture Archiving and Communication System in a Saudi Arabian Hospital Radiology Department"[7]	To assess PACS acceptance among radiology staff.	PACS improved image access and workflow, but training and user resistance remained concerns.	Supports the importance of user acceptance and training in PACS adoption.
"User Acceptance of Picture Archiving and Communication System in the Emergency Department" [10]	To identify factors affecting PACS use in emergency care.	Usefulness, usability, system quality, and organizational readiness influenced adoption.	Supports usability and organizational readiness as design requirements.
"The Adoption of Healthcare Information Systems within Public Hospitals in Kurdistan Region of Iraq" [4]	To study healthcare information system adoption in Iraqi public hospitals.	Cost, limited IT expertise, and weak implementation planning affected adoption.	Provides local evidence on digital healthcare adoption constraints in Iraq.
"PACS Implementation Challenges in a Public Healthcare Institution" [8]	To examine PACS implementation from a vendor perspective.	Infrastructure, storage capacity, and system maturity were key implementation issues.	Supports the need for infrastructure-aware and maintainable PACS design.
"Image Exchange in the Middle East: A Survey" [9]	To investigate medical image exchange in the region.	Structured exchange and interoperability were essential for imaging workflow.	Supports interoperability and workflow integration as core requirements.
"Picture Archiving and Communication Systems: Past, Present, and Future" [11]	To review PACS development and future direction.	PACS evolved from image access and archiving into workflow-centered imaging infrastructure.	Supports treating PACS as an engineering platform rather than storage only.
"Thirty Years of the DICOM Standard" [12]	To review the role of DICOM in medical imaging	Medical imaging data can be stored, sent, and interoperable according to the DICOM standard.	Supports the importance of standards-based PACS design.

3. RESEARCH METHODOLOGY

In order to determine requirements for users and obstacles to implementing a PACS-based medical imaging system in Iraqi healthcare institutions, this research study used a quantitative, questionnaire-based methodology. The approach gathered feedback from participants in the technology and healthcare fields, looked at workflow limitations, and converted the results into engineering design specifications. The methodological workflow used in this study is shown in Figure 1. The process began with questionnaire design and participant selection, followed by data collection, descriptive analysis, requirement identification, and engineering design recommendations.

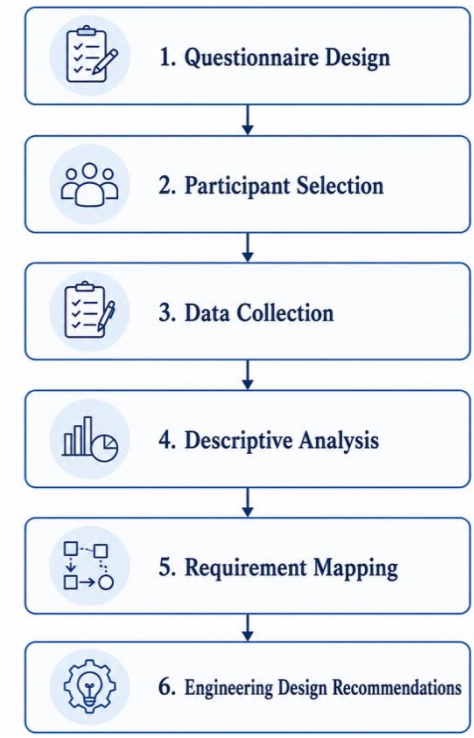

Figure 1. Research methodology workflow

The descriptive data that were gathered from a questionnaire were not treated only as descriptive answers but also used as a cornerstone for building the PACS system, as shown in Figure 1. They were translated as recommendations for the design and engineering requirements for the proposed PACS-based system.

3.1 STUDY DESIGN

A cross-sectional questionnaire served as the primary instrument for gathering data. Requirements engineering, which considers user responses as both answers and inputs for developing functional as well as non-functional requirements as well as system-level constraints, was employed in the study's design. When system requirements are established prior to implementation, this approach works well in the early design stage.

Four main topics were covered in the questionnaire: the participants' background information, their familiarity with the PACS, the hospital's current workflow issues, and the future system requirements. The primary adoption barriers were then determined by analyzing the gathered data and connecting them to the consequences of PACS design.

3.2 PARTICIPANTS AND SAMPLING

Sixty people with technical and medical backgrounds participated in the study. Clinical staff, healthcare professionals, hospital administrators, IT personnel, and individuals engaged in medical or hospital information workflows were among the various healthcare positions represented by those who participated.

Purposive sampling was used to obtain rich information related to the hospital workflow, especially in the medical imaging department. Participants were selected because they work closely with the PACS and system requirements. This helped ensure that the collected responses reflected the practical requirements of PACS design. Participants

were notified of the questionnaire objectives, the forms were filled out by the participants voluntarily, personal information was kept private, and responses were fully analyzed.

3.3 QUESTIONNAIRE STRUCTURE

The questionnaire consisted of three main sections of the questionnaire. Age group, gender, workplace type, and professional role were among the demographic and professional background data gathered in the first stage. The participants' familiarity with the PACS, their past experiences with it, and their perceived limitations in current hospital workflow at the hospital were all addressed in the second section. The engineering specifications of the suggested PACS-based system, such as ease of use, reliability, maintainability, security, privacy, interoperability, retrieval speed, and integration with existing hospital systems, were covered in Section 3.

Table 2: Questionnaire structure

Section	Content	Purpose
Section 1	Demographic and professional background	To describe participant characteristics
Section 2	PACS awareness and workflow challenges	To identify current limitations and adoption barriers
Section 3	Functional and non-functional requirements	To extract engineering requirements for PACS design

Participants' general expertise, their own experiences with the PACS, and engineering specifications were the next topics covered in the questionnaire. Answers might be viewed as feedback on design rather than as general user opinions due to this arrangement. The purpose of the questionnaire was to obtain functional as well as non-functional requirements. The system's features, such as study management, reporting, image uploading and retrieval, and patient registration, are described in the functional requirements. Non-functional requirements include things like scalability, ease of use, responsiveness, stability, security, privacy, and maintainability.

3.4 DATA ANALYSIS

Descriptive statistical methods were used to analyze the answers that were gathered. Both frequencies and percentages were used to provide a summary and quantitatively code closed-ended responses. The requirements that participants considered essential or significant were determined by aggregating the answers to questions that employed significance levels. Answers that were open-ended or related to specific requirements were analyzed and classified based on their engineering importance.

Three steps were taken in the analysis: First, percentages were used to summarize the primary workflow limitations and awareness levels of the PACS. Second, the most frequent needs were divided into two categories: non-functional and functional. Third, engineering design solutions corresponded to reported issues. For instance, retrieval performance and database indexing were associated with patient data access delays, but validation of input and controlled procedure design were associated with data entry mistakes.

The goal of a descriptive study was not to establish a causal connection between participant characteristics and PACS adoption.

4. RESULTS AND DISCUSSION

The outcomes of the questionnaire show the current readiness of Iraqi healthcare institutions to use PACS. The study concentrated on three key areas: the participants' experience with PACS, the main workflow problems impacting the processing of medical images and patient data, and the requirements that should be considered when creating a PACS-based system. In order to convert the questionnaire outcomes into design priorities, the results are examined from a requirements engineering perspective.

A. Participant Profile

Sixty participants with medical, administrative, and technical backgrounds answered the questionnaire. The participants were chosen from different institutions, private and public hospitals, medical clinics, medical colleges, and research centers.

The variety of participants was useful for implementing the PACS system because different user groups have different interests. Clinical users focus on patients' information, image access, and reporting, while the technical and administrative staff pay attention to system operation, integration, and access control and maintenance, the responses collected from these groups provide an important basis for identifying the problems and obstacles that face the system requirements from different workflow perspectives.

B- PACS Awareness and Practical Experience

The practical experience of participants was analyzed to measure how they could learn and work with the PACS system before implementation. The results are shown in the figure. 2.

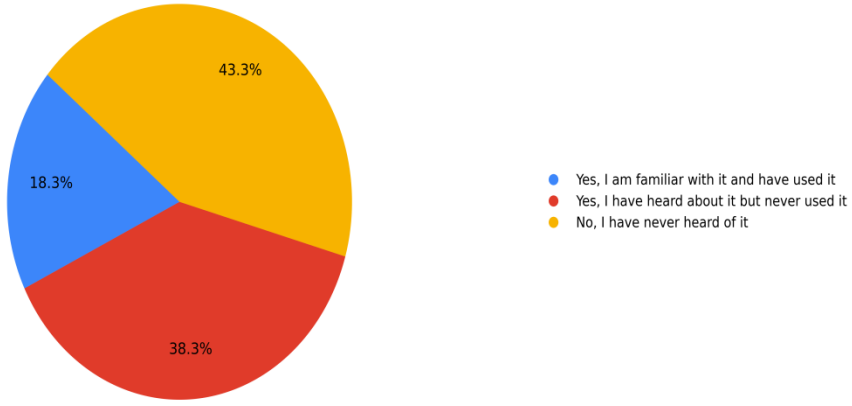

Figure 2. Practical experience of participants in PACS

The results show 18.3% of participants who were familiar with the PACS system and had used it. But the other responses, that 43.3% had heard of PACS but had never used it. The last 38.3% had no prior knowledge of the system. So the responses refer to the lack of experience needed to transfer the system to the real world and apply it. Based on these results and because of the limitations of knowledge and lack of experience, all these reasons required building a simple and usable system that was easy for users to operate. The system should include an easy interface, clear workflow procedures and user training, accessibility, and flexible functions that support future use. Instead of being a follow-up task, user readiness should be incorporated into the implementation strategy.

C- Current Workflow Challenges

The questionnaire also looked into important problems with workflow that have an effect on hospital imaging and information management. Figure 3 shows the most significant difficulties.

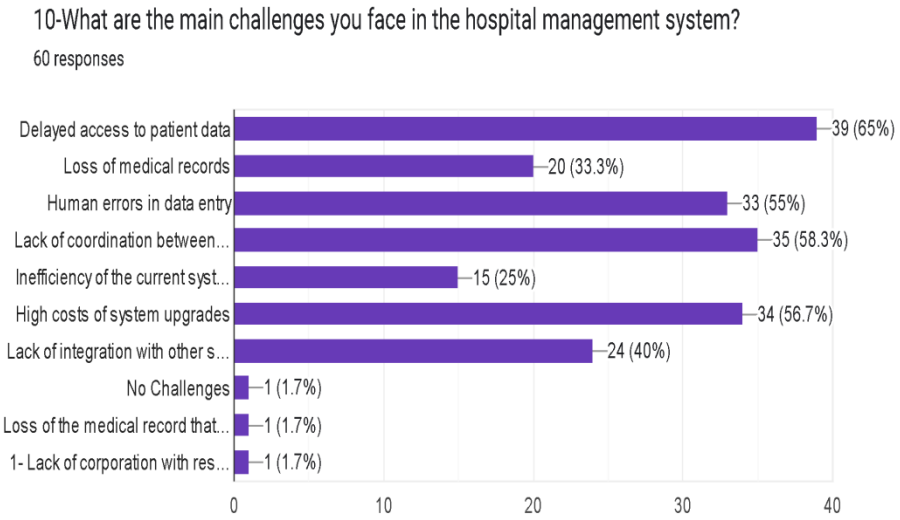

Figure 3. Main workflow challenges affecting hospital imaging and information management

One of the most frequent problems, as indicated by 65% of the participants, was delayed access to patient information. 58.3% of the participants referred to manual data entry problems and the absence of system coordination, and 56.7% stated the costs of system updates. Moreover, 40% of the participants indicated that a major obstacle was the lack of integration with other systems.

These outcomes show that workflow problems include retrieval speed, data quality, system integration, cost, and coordination between departments, in addition to image storage. From the point of view of systems engineering, these difficulties result in particular design specifications. An organized structure for databases and indexed retrieval is necessary for delayed use. Validation procedures, control input fields, and standardized forms are necessary to prevent human data entry errors. Future compatibility with hospital information systems and integration strategies is necessary due to interoperability limitations. Because the cost of implementation is high, the need appears to be for a modular and phased installation.

D- Functional Requirements

The PACS system must support the fundamental functions of the medical imaging workflow, based on the questionnaire results. Patient registration, study creation, image uploading, retrieval, and display, report generation, and managing patient information access are some of these functions.

Based on the survey outcomes and their engineering significance, the main functional requirements described in Table 3 were determined.

Table 3: Functional requirements for the proposed PACS-based system

Requirement Category	Functional Requirement	Engineering Meaning
Patient management	Register and retrieve patient information	Structured patient database and searchable patient records
Study management	Create imaging studies and link them to patients	Relationship between patient, study, modality, and image records
Image management	Upload, store, retrieve, and display medical images	PACS repository, image-path handling, and viewer integration
Workflow support	Support reception, radiology, diagnosis, and administration roles	Role-based workflow and access separation
Reporting	Generate structured diagnostic reports	Report template, report storage, and export function
Search and retrieval	Locate stored images efficiently	Indexed repository and optimized retrieval mechanism
Interoperability	Support future connection with hospital systems	API layer and compatibility planning

Patient information, medical imaging, image storage, viewing, reporting, and access control must all be integrated into a single workflow by the necessary PACS system. This means that the system should be regarded as an organized framework for managing medical imaging data rather than as a simple image viewer.

E- Non-Functional Requirements

The predicted level of system performance during frequent usage is defined by non-functional requirements. In this study, security, privacy, performance, scalability, interoperability, ease of use, reliability, and maintainability were identified as essential criteria for the proposed PACS-based system. The responses showed the important features of usability, reliability and maintainability. Therefore, these requirements are presented in Figure 4 as the most important non-functional requirements.

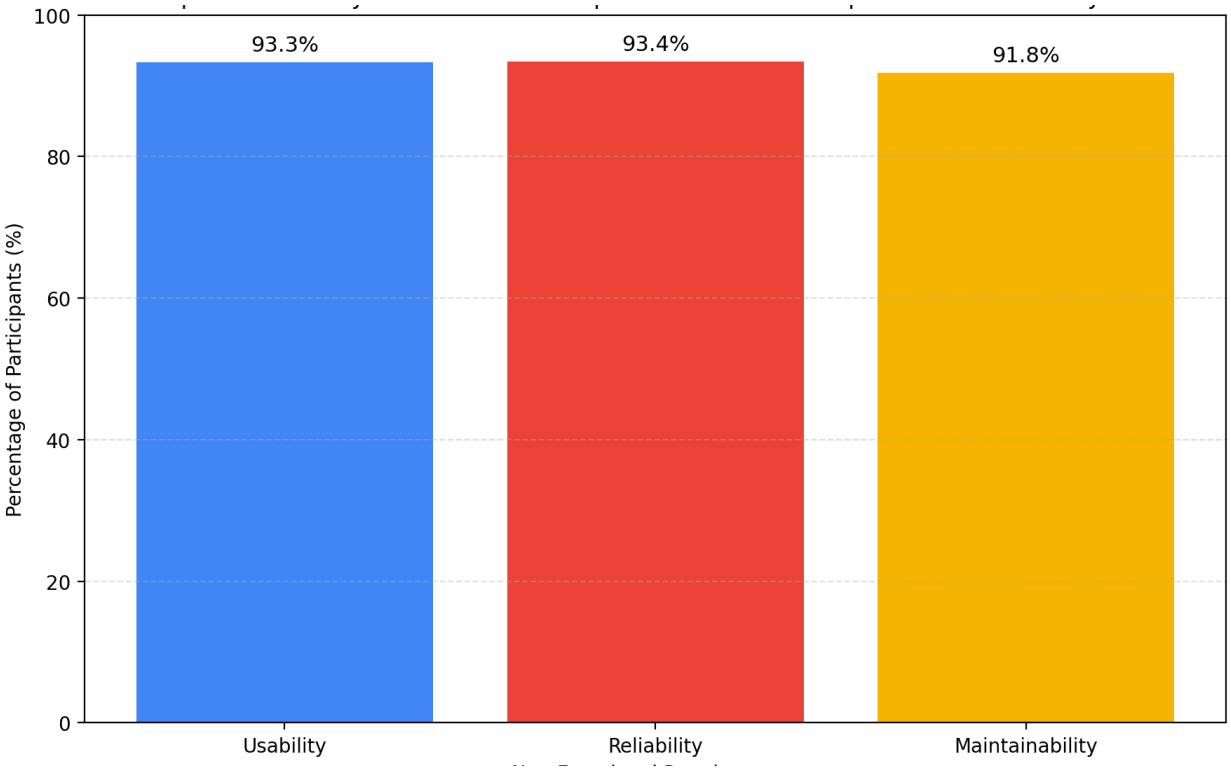

Figure 4. Non-functional requirements of the proposed system

Usability, reliability, and maintainability received the highest percentages in the responses of the participants and were ranked as very important; the percentages were: Reliability reached 93.4%. The second percentage for usability reached 93.3%, and the last for maintainability reached 91.8%. The participants expected an easy system and reliable in daily work, and could depend on it for their tasks.

The non-functional requirements are fundamental to the design of the system because they are directly related to the important parts, including reliability, security, performance, interoperability, and scalability, that supports the system for the long term. These requirements are summarized in Table 4.

Table 4: Non-functional requirements and design implications

Non-functional	Design implications
Usability	Simple interface, clear navigation, and reduced training burden
Reliability	Stable operation, backup strategy, UPS support, and failure-recovery planning
Maintainability	Modular design, clear documentation, manageable update process, and local technical support
Security	Authentication, role-based access, audit logs, and protected storage
Privacy	Controlled access to patient information and medical images
Performance	Fast image retrieval and responsive viewing
Scalability	Ability to support more users, studies, and departments
Interoperability	Compatibility with existing and future hospital data workflows

The results show that the PACS system depends on reliability, security, and data privacy in everyday hospital work, in addition to other system functions. Technically sophisticated systems that are challenging to set up and maintain may not be commonly used, particularly in settings with limited resources.

F- Engineering Requirement Mapping

The determined workflow challenges were associated with technical requirements, and design solutions were offered in order to make the data from the survey appropriate for use in system design. This connection is shown in Table 5.

Table 5: Mapping of reported workflow problems to engineering design requirements

Reported Problem	Engineering Requirement	Suggested Design Response
Delayed access to patient data	Retrieval performance	Indexed search, structured database, and optimized query design
Human data-entry errors	Input validation and workflow control	Required fields, dropdown menus, validation rules, and audit trail
High upgrade cost	Cost-aware architecture	Modular deployment, open-source components where possible, and phased implementation
Weak interoperability	System integration	API layer, standardized data exchange, and compatibility with existing workflows
Data-security concerns	Security engineering	Role-based access, authentication, and encrypted storage or communication
Limited user familiarity	Usability engineering	Simple interface, user training, guided workflow, and user documentation
Maintenance difficulty	Maintainability	Modular codebase, clear database structure, backup, and recovery plan

The adoption challenges that participants observed could be converted into particular engineering requirements, as Table 5 illustrates. For example, using indexed retrieval and an organized design of databases can help with patient data access delays. Regulated fields and input verification may decrease human data entry. Role-based access, authentication, and secure data storage are necessary for security concerns. An architecture that is ready for integration is necessary due to interoperability constraints.

This study describes the problems and the obstacles faced by the participants of the questionnaires that can lead to finding the appropriate solutions and guidance to building the design, therefore being not only descriptive survey data but also prescriptive. Gave priority to security, flexibility, maintainability, operational compatibility, and multi-staged implementation. The PACS system is not only for storage and retrieval but should be design to work with real hospital workflows.

5. RECOMMENDATIONS

Based on the outcomes of the questionnaire that was derived and the engineering requirements for building such a system, the important recommendations are summarized below as a baseline.

1. **Implementation in a multiple-step approach**
   The PACS system should first be deployed in specific sections for testing, such as radiology and diagnosis, and then extended to the other hospital departments.
2. **Prioritize the Training and awareness for implementing the system**
   System users must receive practical training to learn how to use the system components, such as registration, medical image upload, reading and analyzing the outcomes, and viewing reports and access permissions.
3. **Improving data organization and retrieval accuracy**
   The database should be designed to support fast search and retrieval using patient identifiers, study date, report status, and anatomical region. Proper indexing and structured metadata are required to reduce retrieval delays.
4. **Supporting security and achieving an integrated system**
   The system should include authentication, role-based access, audit logs, secure storage, backup procedures, and future integration with hospital information systems and electronic medical records.
5. **Use maintainable intelligent model architecture**
   The system must be ordered into separate parts for patient management, study management, image storage, visualization, reporting, administration, and future intelligent imaging functions.

The PACS system must be applicable in Iraq gradually and in a secure manner, easy to maintain, resolving common problems, and compatible with the daily loaded work in Iraqi hospitals and flexible to be extended in the future.

6. CONCLUSION

This study introduced and explained the implementation of PACS requirements that are needed on the engineering side, with the obstacles that face it, when it is employed in Iraqi healthcare institutions. The responses to the questionnaire were from participants with a medical and technical background who are close to the field. Demonstrate through these responses the weak knowledge of the PACS system and no use of such a system in their

hospitals or medical institutions. For many reasons, for instance, weak infrastructure, the costs of the resources and maintaining the system needed to build such a system, and the limited number of experts and practitioners. All these lead to a slow workflow, late access to patients' files, disorganization, and mistakes in entering the information as a result of the workload. The questionnaire also included functional and non-functional requirements, in addition to those related to the engineering design. Reliability, security, maintainability, and documentation of patients and retrieval of similar image cases; privacy of data; and scalability and interoperability were derived from these results. The implementation of the PACS system in Iraqi healthcare institutions involves multiphase engineering processes. Based on model building and training, data preparation and processing, securing the system, and system integration planning, rather than simply installing software, the study provides a practical framework and design guidelines for implementing PCAS for future use in Iraq.

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