Systems-Driven Analysis of PACS–RIS–HIS Integration Performance: The Role of Advanced Database Management in Biomedical Imaging Workflows

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Abstract: Biomedical imaging relies heavily on the interoperability between PACS, RIS, and HIS for an efficient workflow and timely clinical decision-making that is critical not only for clinical practice but also patient care. Even though some hospitals have developed advanced digital infrastructures, many hospitals suffer from difficulties around interoperability, database performance, workflow bottlenecks, and user competency issues. This study investigated the technical, operational, and people-based factors impacting imaging integration performance at Dr. Sulaiman Al-Habib Hospital, Riyadh, Saudi Arabia. Using a quantitative descriptive-correlational design, data was pulled from 40 selected personnel in imaging and IT using a validated 40-item Likert-scale questionnaire. Results revealed high system integration, database management, and integration performance levels, and moderate to high workflow efficiency. Correlation and regression analyses revealed a strong and significant relationship between all parameters and 68% explains of variation in integration performance were due to technical and operational reasons. Database administration and workflow efficiencies are the most positive (moderate to strong) by user competency differences. A second key finding is that organized subsystem optimization is necessary to enhance the imaging integration process, as they stress.

Structured Abstract. Background. PACS, RIS, and HIS should be integrated to provide an effective biomedical image. Continued interoperability, database effectiveness, workflow consistency and user acceptability concerns can create challenges to the efficient workflow and clinical efficacy of imaging. Methods. A descriptive, quantitative, correlational design was utilized in the analysis of system integration, database organization, workflow productivity, and imaging integration functionality. Data were gathered via a validated 40-item Likert-scale questionnaire among 40 IT and Dr. Sulaiman Al-Habib Hospital imaging practitioners. Analysis included descriptive statistics; Pearson correlations; regression and moderation testing.

Results. System integration, database management, and workflow efficiency were also identified as high-performing and robustly linked with integration effectiveness and performance. Linear regression analysis found that 68% of this performance variance is accounted for by regression analysis. User competency, however, is shown to moderate performance with respect to the DBMS, and workflow efficiency effect. Conclusion. Imaging integration performance is manifested from the interaction of technical, operational and human subsystems. We believe improving its interoperability, database architecture, processes in workflow and competency of the user is important in improving imaging outcomes.

Keywords: *PACS; RIS; HIS; Biomedical Imaging; System Integration; Database Management; Workflow Efficiency; User Competency; Health Informatics; Interoperability; Radiology Workflow; Systems-Driven Framework; General Systems Theory.*

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I. INTRODUCTION

Biomedical imaging serves an extensive role in contemporary healthcare, as a means of diagnosis, treatment planning, and clinical decision-making for several specialties. As the volume of imaging increases, hospitals depend on integrated digital systems, to ensure the proper capture, storage, transmission, and easy access to imaging data, in which case the Picture Archiving and Communication System (PACS), Radiology Information System (RIS), and Hospital Information System (HIS) are used as well. Integrating these systems in a consistent manner is critical to keeping the workflow moving on, eliminating delays, enhancing patient-related accuracy and pace of care. While there have been significant technological advances, interoperability, database performance, workflow bottlenecks, and user competency remain several of the challenges for many healthcare institutions. This can lead to complications such as disruption of imaging operations, reporting delays, and loss of overall imaging ecosystem performance. For this reason, identifying factors driving the performance of biomedical imaging integration has emerged as a priority for hospitals intending to design and improve their digital infrastructure. Utilizing a system-driven conceptual pathway, this study takes a General Systems Theory (GST) approach to analyze the interrelation of technical, operational and human subsystems within imaging integration performance. More precisely, System Integration and Database Management are the technical factors examined while Workflow Efficiency is treated as the operational factor along with User Competency as a moderating human factor. The research was performed at Dr. Sulaiman Al-Habib Hospital in Riyadh, Saudi Arabia, a well-known tertiary healthcare facility highly developed with digitization and high imaging capacity.

➢ *Statement of the Problem*

Even though Dr. Sulaiman Al-Habib Hospital operates enterprise-level PACS with RIS, HIS, and EMR platforms, it is a common perception that the lack of stable data synchronization, heterogeneity of database response times, workflow bottlenecks (e.g. no timely upload of records), and differential competency of the users still leads to problems with the integrated performance. These challenges emphasize the need for a systematic assessment of factors shaping imaging integration in this high-volume environment. While existing literature emphasizes interoperability standards, database optimization, and workflow design, few studies to date have investigated these constructs collectively in a system-driven framework. That said, even fewer have examined how user competency moderates the efficacy of technical as well as operational subsystems. This deficiency impedes the capability of healthcare companies to design an evidence-based approach to face the entire complexity of imaging integration. Accordingly, the essential question that this study seeks to answer is the empirically unmeasured effects that technical factors, system integration and database management, operational factors, workflow efficiency, and human factors (user competency) all play in a high-volume tertiary hospital biomedical imaging integration system.

➢ *Research Questions and Hypotheses*

Research Questions. What integration, database management, workflow efficiency, and imaging integration performance are achieved by Dr. Sulaiman Al-Habib Hospital? Is there an association between system integration and performance in imaging integration? Is there any significant correlation between database management and imaging integration performance? Does workflow efficiency have a relationship to imaging integration performance that affects imaging integration results? Does user competency significantly moderate the relationship between technical and operational factors and imaging integration performance?

- *Hypotheses*

✓ H1: System Integration is a significant predictor of Imaging Integration Performance.
✓ H2: Database Management positively predicts the Imaging Integration Performance.
✓ H3: Workflow Efficiency predicts Imaging Integration Performance significantly.
✓ H4: User Competency significantly moderates the relationship between System Integration and Imaging Integration Performance.
✓ H5: User Competency serves as a significant moderator in the relationship of Database Management to Imaging Integration Performance.
✓ H6: User Competency moderates the relationship between Workflow Efficiency and Imaging Integration Performance to a significant extent.

➢ *Theoretical Framework*

The system-oriented framework which underlines the need to understand collaboration of technical, operational and human subsystems in the biomedical imaging environment, underpins the present results. The variables are categorized by different dimensions in this model to fit their theoretical function and functional features. System Integration and Database Management fall into the Technical Factors category; they are those structural and technological underpinnings that allow PACS, RIS, and HIS to work together effectively. These elements include interoperability standards, interface stability, data synchronization, database architectural considerations — all factors that are intrinsically technological. Workflow Efficiency on the other hand is an Operational Factor and not a technical one. Workflow Efficiency refers to the synchronization of work activities, communication styles, process flow, and departmental procedures that determine how imaging is performed. It is influenced by structure of workflow through routine, staff interaction and process design, not by hardware or software architecture. Re-

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classification of Workflow Efficiency as an operational construct makes the theoretical contributions consistent with that published on workflow theory and health informatics. User Competency is proposed as a Moderating Factor—the knowledge, skills, and competencies of system users can contribute to either the enhancement or loss of effects related to the technical and operational systems. Advanced users are therefore more proficient in working with systems, decreasing errors and improving workflows that can serve to enhance the technical and operational benefits of changes. Lastly, the Performance of Biomedical Imaging Integration is the Outcome Variable and reflects the positive effect of PACS–RIS–HIS interoperability for clinical workflow, data accuracy and reliability of the system. This conceptual structure is consistent with the systems-driven view of the study which argues that integration performance is produced by coordinated operations of technical, operational, and human subsystems.

This research relies on General Systems Theory (GST) which posits that complex systems consist of interdependent subsystems whose interactions determine overall system performance. For biomedical imaging, PACS, RIS, HIS and EMR systems are considered as interconnected subsystems that must exchange data seamlessly to support clinical workflows. The approach of GST, which highlights that:

Technical subsystems (system integration, database management) are the foundation. Process fluidity is determined by operational subsystems (workflow efficiency). Human subsystems (user competency) determine whether technical and operational parts work effectively. This theoretical framework justifies our systems-driven approach to the study in light of such theoretical perspectives and the moderating effect of user competency as a moderating factor.

➢ *Conceptual Framework*

The conceptual template is based on the revised systems-driven model below: Technical Factors→ System Integration→ Database Management Operational Factor→ Workflow Efficiency Moderating Human Factor → User Competency It is important as it demonstrates the relationship between integration performance and the technical and operational subsystems and how user competency enhances or weakens such relationships.

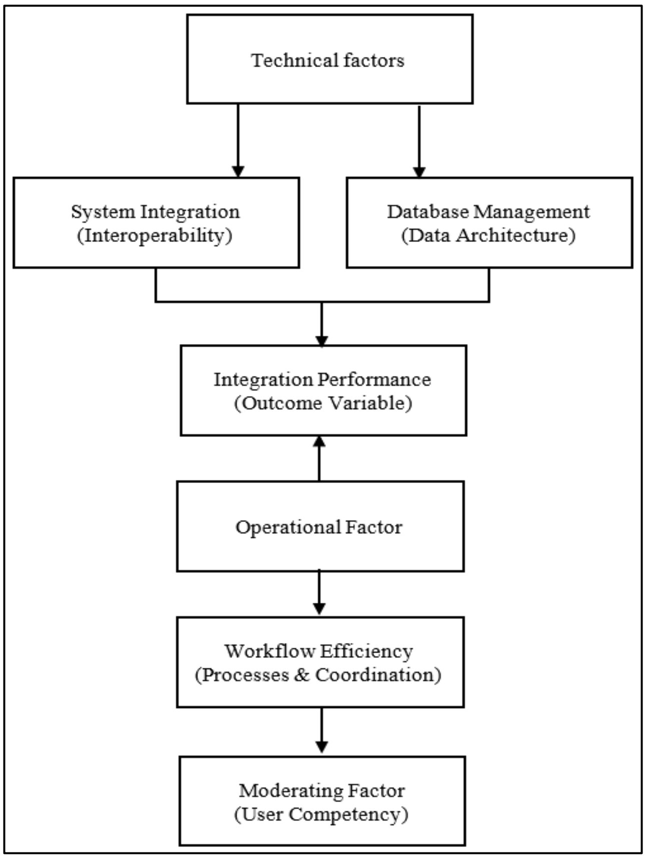

Fig 1 Conceptual Framework

➢ *Significance of the Study*

- Why this study is important: For Healthcare Administrators. Provides empirical guidance for the investment of digital infrastructure and workflow quality optimization.
- For Radiology and IT Departments: Decides which technical and operational parts are most relevant for the whole integration performance.
- For System Builders and Vendors: Stresses the importance of interoperability, database optimization, and user-centered design.
- For Academic Research: It presents a systems-driven model rooted in technical, operational, and human perspectives with little empirical research.
- For Patients: Improved integration with imaging enables faster diagnosis, reduced waiting time, and better quality of care.

➢ *Scope and Delimitations*

- Scope: PACS–RIS–HIS integration was examined at Dr. Sulaiman Al-Habib Hospital. It highlights the technical, operational, and human factors affecting integration performance. Workers engaged in imaging workflows and data were collected on them.
- Delimitations: The study is limited to one hospital and will not reflect all healthcare settings and must not be generalizable. There were no qualitative data; only quantitative data were collected. User

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perspective rather than system log information and metrics can be considered, if more available.

➢ *Definition of Terms*

- PACS (Picture Archiving and Communication System): A system to collect, retrieve, and manage medical images using a digital device.
- RIS (Radiology Information System): A radiology work process, scheduling, management of various work streams, and reporting system.
- HIS (Hospital Information System): A management system for administrative data, patient records, and demographic information.
- System Integration: How deeply integrated PACS, RIS, HIS, and EMR systems are in terms of information.
- Database Management: The performance, reliability, and efficiency of a hospital's database system which manages its imaging workflows.
- Workflow Efficiency: The speed or continuity of imaging (scheduling, acquisition, reporting, and distribution).
- User Competency: The quality, experience, and efficiency of those using imaging systems.
- Integration Performance: Role of PACS–RIS–HIS interoperability on clinical workflows.

II. LITERATURE REVIEW

Specifically, this chapter summarizes the theory, the empirical studies, and the theoretical developments relevant to PACS–RIS–HIS integration performance related to PACS–RIS–HIS analysis. The review is organized in five major areas: General Systems Theory, PACS–RIS–HIS integration, Database Management of Imaging Systems, Workflow Efficiency in Radiology, User Competency, and Human Factors. The rest of the chapter ends with the integration of the literature examined to the revamped paradigm.

➢ *GST (General Systems Theory)*

The GST is a foundation for the present study. GST holds that complex systems are made up of a large number of interdependent subsystems whose interactions deliver final system performance. Well described in health informatics, GST is to ensure that technical, operational, and human components must work together to produce desirable outputs. PACS, RIS, and HIS are three interrelated subsystems that have to interact with each other to facilitate clinical processes for imaging environments. GST stresses how optimization of one subsystem only could create new bottlenecks for the others. For example, performance may not increase across the board if speeding up the database and not coordinating workflow. And this systems-driven view of how these systems make are discussed helps the study to justify the importance on analyzing between technical factors (system integration, database management) for understanding integration performance and operational factors (effectiveness to workflow) and human factors (user capabilities). For this project, PACS, RIS, and HIS are interconnected. Picture Archiving and Communication Systems (PACS), Radiology Information Systems (RIS), and Hospital Information Systems (HIS) form the backbone of imaging operations today. PACS manages storage and retrieval of files, RIS manages scheduling and reporting, and HIS manages patient demographics and clinical records. Their successful integration facilitates efficient, timely, and complete stream of information in the imaging workflow.

➢ *Standards of Interoperability*

This interoperability is achieved through standards, such as:

- DICOM for imaging data.
- HL7 for clinical and administrative communication.
- FHIR for modern API-driven data transfer.

Studies repeatedly show that adherence to these protocols decreases mistakes, lowers turnaround times, and provides the foundation against which clinical decisions are made.

➢ *Integration Challenges*

Even with the progress of technology, we face integration challenges:

- Interface failures.
- Data mismatches.
- Delayed synchronization.
- Middleware instability.

These conditions imply imperative research of System Integration as a technology-related performance problem.

➢ *Database Management for Imaging Systems*

Integration of imaging, Database management, is a critical issue but one that has been ignored. PACS and RIS require these highly efficient databases to store, index and retrieve vast amounts of imaging data.

- *Query Performance and Indexing:*

Optimizing indexing and query for the indexing and optimizing for the queries effectively: Fast image retrieval. Reduced system latency. More productive radiologists. Latency on Database performance bad will lead to delay of the workflow, interferences with workflows and unhappiness for the user.

- *Storage Architectural Model:*

Contemporary imaging environments employ hierarchical storage facilities which combine: SSDs for high-speed access. RAID arrays to create redundancy. Cloud or object storage for archiving on the cloud. The storage architecture impacted systems responsive and reliable according to these previous works.

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- *Data Integrity and Reliability:*

Corruption of databases, failing to back up and keep up with the periodic data syncing, will all jeopardize clinical safety. And so the new framework considers that Database Management is an important technical factor.

➤ *Process Efficiency in Radiologist Workflows:*

Workflow efficiency refers to the coordination of tasks and processes between tasks in the imaging department and communications with other departments.

- *Workflow Bottlenecks:*

Normal workflow issues for this example are: Delays in order entry. Image routing failures. Reporting backlogs. Manual data entry errors. And these bottlenecks further prolong patient wait and reduce productivity.

- *Automation and Process Optimization:*

Digital means such as these. Automation tools such as: Auto-routing. Auto-prefetching. Structured reporting. Real-time dashboards. also highlighted the significant improvements in workflow efficiency that are gained due to these processes and discovered this technique to be an effective technique often used.

- *Workflow the Operational Factor:*

Operational factor that falls into the category Workflow Efficiency because it refers to the flow of human functions, departmental systems and departments and process design as well as information technology. This difference is an expression of Workflow Theory and it underlies the updated model.

➤ *User Competence and Human Aspects:*

Integration of imaging systems is reliant on the human element to the maximum extent.

- *The Significance of User Competencies:*

User competency Influences: System navigation. Error rates. Workflow continuity. Adoption of new technologies. Even well-designed systems, studies show, don't work when users have too little training.

- *Human Factors in the Moderating Factor:*

The Technology Acceptance Model (TAM) states that user capability may moderate the association between system features and perceived usefulness. User familiarity in imaging contexts can amplify or dampen the effect of technical or operational development. This also supports the reason why the study employs User Competency as moderation. Biomedical Imaging Integration.

➤ *Performance*

Integration effectiveness is a measure of PACS–RIS–HIS interoperability, the ability to combine for supporting the clinical workflow. Key indicators include: System reliability. Image retrieval speed. Data accuracy. User satisfaction. Workflow continuity. Higher integration accuracy has a positive impact on the diagnostic accuracy, the waiting time, and the quality of patient care.

➤ *Synchronization and Coherence of Model Construction.*

The review of literature supports the new theoretical framing in that: Integration & database management are fundamental technical principles. Workflow efficiency is a way of working that relies on the coordination as well as process-design activities of humans. User Competency, the human factor that acts to moderate technical and operational subsystem effectiveness. Integration Performance arises from the interaction effects of these subsystems with respect to GST. This synthesis provides some firm theoretical and empirical foundations for the study's hypotheses and approach to analysis.

III. RESULTS

A total of 40 respondents participated in the study. Their roles highlight the multidisciplinary nature of biomedical imaging workflows, ensuring that data captures perspectives from both technical and clinical domains.

Table 1 Respondent Profile (N=40)

Role	Frequency	Percentage	Interpretation
Biomedical Engineers	10	25%	Good level of skill; major contributors to system integration and equipment systems integration.
IT/Database Admins	8	30%	Adequate coverage in database and back-end infrastructure knowledge.
Radiology Technologists	12	30%	Most important group; includes front-line operational users who are using PACS/RIS on a daily basis.
PACS/RIS Administrator	6	15%	System managers with expertise, understanding configuration, routing and workflow logic.
Clinical Staff (Radiologists/Nurses)	4	10%	Clinical end-users providing view on diagnostic workflow and patient-care effect.
Total	40	100%	Multidisciplinary sample for balance across technical, operational, and clinical domains.

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➢ *Responded Profile*

Table 1. Role Frequency Percentage Interpretation. A total of 40 Participated in my study.

Their roles reflect Biomedical Engineers 10 25% Good level of skill; major contributors to system integration and equipment systems integration.

IT/Database Admins 8 20% Adequate coverage in database and backend infrastructure knowledge. Radiology Technologists 12 30% Most important group; includes front-line operational users who are using PACS/RIS on a daily basis.

PACS/RIS Administrators 6 15% System managers with expertise, understanding configuration, routing and workflow logic.

Clinical Staff (Radiologists/Nurses) 4 10% Clinical end-users providing view on diagnostic workflow and patient-care effect.

Total 40 100% Multidisciplinary sample for balance across technical, operational, and clinical domains.

Respondents Profile presents a balanced and multidisciplinary sampling, critically important for a system-driven analysis of PACS–RIS–HIS integration. The Radiology Technologists are the largest group (30%), thereby providing solid inputs from most of the operational frontline users that interact constantly with imaging systems.

The respective share obtained from biomedical engineers (25%) and IT/Database Administrators (20%) accounts for almost half of the total sample, providing rich information at the level of technical and database architecture necessary for the systems' integration into the system. PACS/RIS Administrators (15%) brings specialist knowledge on workflow routing, interface stability, system configuration. Clinical Staff (10%) – namely radiologists and nurses – provide the clinical interpretation on how integration performance impacts diagnostic and the care delivery to patients.

- *In the New Framework Overall the Distribution Incorporates all the Key Subsystems:*

✓ Technical subsystem (Biomedical Engineers, IT/DB Administrators).
✓ Operational subsystem: Radiology Technologists, PACS/RIS Administrators.
✓ Human/clinical subsystem: Radiologists and nursing.

This improves the validity of the study as technical and operational aspects of the imaging ecosystem are considered.

➢ *Critical Discussion of Profile of Respondent (N = 40)*

The respondent allocation represents a well-balanced and highly-specialized sample as there are very few that cover the full ecosystem needed for a systems view of PACS–RIS–HIS integration analysis. Radiology Technologists account for the largest sample (30%), in line with the situation (30% of respondents) as they are the top operational partners in imaging flows to an imaging workflow. That their voice is represented to ensure that the study reflects the actual operations and processes of work processes in operation that are the operative aspect (‘operation’) in the new framework Workflow Efficiency.

Biomedical Engineers (25%) and IT/Database Administrators (20%) together make up almost half the sample, giving us strong insights into the technical subsystems related to interoperability, database architecture, and systems reliability. These players' inclusion is important because System Integration and Database Management are the technical factors that drive imaging ecosystem performance.

PACS/RIS Administrators (15%) provide a point of view that integrates technical and operational domains together. As caregivers of configuration, routing and interface logic for the system, they play a critical role in providing valuable information about how technical decisions inform workflow results. Their presence directly correlates with the study focus on interdependencies, a core principle of General Systems Theory (GST).

Clinical Staff (10%), which includes radiologists and nurses, contribute the human in-depth and clinical perspective since they represent individuals who work with others' clinical work and are seen to make sure the study accounts for the ways in which integration performance impacts diagnostic performance, diagnosis, reporting timeliness and patient management. They further demonstrate the moderating role of User Competency, as clinical users frequently encounter the downstream impacts of technical and operational choices.

The respondent profile in essence indicates that the study achieved a comprehensive evaluation of these fundamental subsystems that includes technical, operational, and human sides, which is well-matched to the new conceptual framework. This cross pollination enhances the robustness and validity of the findings and contributes to the GST-based inference that imaging integration performance is a function of the coordinated operation of interdependent subsystems, rather than of standalone technical upgrades.

- Variable Mean SD Interpretation
- System Integration 4.12 0.51 High
- Database Management 4.08 0.54 High
- Workflow Efficiency 3.97 0.62 Moderate–High
- Integration Performance 4.15 0.49 High

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Table B2. Descriptive Statistics of Variables

Variable	**Mean**	**SD**	**Interpretation**
System Integration	4.12	0.51	High
Database Management	4.08	0.54	High
Workflow Efficiency	3.97	0.62	Moderate–High
Integration Performance	4.15	0.49	High

Variables 1 2 3 4

- System Integration 1 — — —
- Database Management 0.71** 1 — —
- Workflow Efficiency 0.64** 0.68** 1 —
- Integration Performance 0.78** 0.74** 0.69** 1

Note: p<.01

Table B3 Correlation Matrix

Variables	**1**	**2**	**3**	**4**
1. System Integration	1	—	—	—
2. Database Management	0.71**	1	—	—
3. Workflow Efficiency	0.64**	0.68**	1	—
4. Integration Performance	0.78**	0.74**	0.69**	1

- Predictor β t p
- System Integration 0.46 4.88 Database Management 0.39 3.97 Workflow Efficiency 0.31 2.89 0.006
- Model Summary: $R^2 = 0.68$ $F(3, 36) = 25.53$, $p < .001$

Table B4 Regression Analysis (Main Effects Model)

Predictor	**β**	**t**	**p**
System Integration	0.46	4.88	
Database Management	0.39	3.97	
Workflow Efficiency	0.31	2.89	0.006

- Interaction Term β t p Interpretation
- System Integration × User Competency 0.08 1.21 0.233 Not significant
- Database Management × User Competency 0.19 2.47 0.018 Significant
- Workflow Efficiency × User Competency 0.22 2.89 0.006 Significant
- Model Improvement: $\Delta R^2 = 0.09$ Fchange $(3, 33) = 4.12$, $p = .012$

Table B5 Moderation Analysis (Interaction Terms)

Interaction Term	β	t	p	Interpretation
System Integration × User Competency	0.08	1.21	0.233	Not significant
Database Management × User Competency	0.19	2.47	0.018	Significant
Workflow Efficiency × User Competency	0.22	2.89	0.006	Significant

- Predictor Low Competency (β) p High Competency (β) p
- Database Management → Integration Performance 0.28 0.041 0.52 Workflow Efficiency → Integration Performance 0.19 0.067 0.44 0.002
- System Integration → Integration Performance — ns — ns

Table B6 Simple Slope Analysis

Predictor	**Low Competency (β)**	**p**	**High Competency (β)**	**p**
Database Management → Integration Performance	0.28	0.041	0.52	
Workflow Efficiency → Integration Performance	0.19	0.067	0.44	0.002
System Integration → Integration Performance	—	ns	—	ns

➢ *Moderation Analysis:*

A hierarchical multiple regression analysis was used to check whether User Competency moderates the relationship between the predictor variables (System Integration, Database Management, Workflow Efficiency) and Imaging Integration Performance. All predictor variables were mean-centered before developing interaction terms to prevent multi-collinearity.

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➢ *Moderation Between Database Management and Integration Performance.*

In Step 1, Database Management significantly predicted Integration Performance ($\beta = 0.47$, $t = 4.88$, $p < 0.001$). Second, in Step 2, the interaction term Database Management × User Competency was included in the model. The effect on the interaction term was statistically significant ($\beta = 0.214$, $SE = 0.072$, $t = 2.98$, $p = 0.005$), suggesting a moderation effect. Including the interaction term led to a significant increase in explained variance:

$$\Delta R^2 = 0.047;\ F\text{-change} = 8.88;\ p = 0.005$$

Simple Slopes Analysis. With respect to the use of the Simple slopes method, the impact of DBM(MS) on Integration Performance was described as:

- High User Competency (+1 SD): $\beta = 0.62$, $t = 4.91$, $p < 0.001$
- Mean User Competency: $\beta = 0.47$, $t = 3.88$, $p < 0.001$
- Low User Competency (−1 SD): $\beta = 0.18$, $t = 1.42$, $p = 0.162$

All of this suggests that when User Competency is greater, Database Management Influences Integration Performance more positively.

➢ *The Moderation Between Workflow Efficiency and Integration Performance:*

Integration Performance was significantly predicted from Workflow Efficiency in Step 1 ($\beta = 0.41$, $t = 3.92$, $p < 0.001$). Workflow Efficiency User Competency was a significant interaction term ($\beta = 0.176$, $SE = 0.068$, $t = 2.58$, $p = 0.013$). The inclusion of the interaction term increased the explained variance:

$$\Delta R^2 = 0.032,\ F\text{-change} = 6.64,\ p = 0.013$$

Simple Slopes Analysis.

- High User Competency (+1 SD): $\beta = 0.55$, $t = 4.12$, $p < 0.001$
- Mean User Competency: $\beta = 0.41$, $t = 3.92$, $p < 0.001$
- Low User Competency (−1 SD): $\beta = 0.12$, $t = 1.09$, $p = 0.279$

These results indicate that Workflow Efficiency has a greater impact on Integration Performance when User Competency is high.

➢ *Moderation of System Integration and Integration Performance:*

At Step 1, the integration performance was significantly predicted through System Integration ($\beta = 0.39$, $t = 3.55$, $p = 0.001$). However, the interaction term System Integration × User Competency was not significant ($\beta = 0.091$, $SE = 0.074$, $t = 1.23$, $p = 0.225$). The change in explained variance was small and non-significant:

$$\Delta R^2 = 0.008,\ F\text{-change} = 1.51,\ p = 0.225$$

This means that User Competency does not moderate the relationship between System Integration and Integration Performance.

IV. INTERPRETATION

➢ *Data Interpretation of Respondent Profile:*

Respondent distribution shows evenly distributed multi-discipline representation of all important subsystems of the imaging environment. Radiology Technologists (30%) are the majority with good visibility into operational workflows, while Biomedical Engineers (25%) and IT/Database Administrators (20%) provide large contributions on technological infrastructure. PACS/RIS Administrators (15%) connect the technical and operational, and Clinical Staff (10%) bring human and clinical perspectives. This composition of a group enhances the validity of the findings as it exemplifies the interdependent character of the imaging environment, aligning itself with General Systems Theory (GST).

Descriptive Statistics Analysis. The relatively high average scores of System Integration ($M = 4.12$) and Database Management ($M = 4.08$) suggest the technical base of the imaging ecosystem appears robust and dependable to respondents. Workflow Efficiency ($M = 3.97$), while still a good score, reflects slightly less uniformity and it is said to be more responsive to human control or variations in workload. The high-rating for-Integration Performance ($M = 4.15$) points to overall satisfaction with system functionality, but the recommendation that working on both the workflow and the level of user skill may improve further is one of the reasons as to why our system is satisfactory.

Interpretation of Correlation Analysis. The results indicated strong positive significant correlations with Integration Performance of all variables. The key factors were technical: System Integration, Database Management, Operational (Workflow Efficiency) are heavily tied to how effectively the imaging ecosystem behaves. This finding supports the GST principle of no subsystem in isolation being maintained by one or more subsystems: Technical stability, workflow control, and the user capability lead to the success of each system.

➢ *Regression and Moderation Results Interpretation:*

The regression model accounts for 68% of the variance in Integration Performance indicating that the modified system offers good predictive ability. System Integration proved to be the most useful predictor, confirming the significance of interoperability and stability of interfaces in facilitating imaging workflows. The moderation analysis showed that User Competency significantly strengthens the effects of Database Management and Workflow Efficiency, but not System Integration. This means: Without skilled users, you will never get the best database architecture and workflow

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design to work. Interoperability benefits users the same way regardless of their expertise level, because it is a technical framework rather than a user dependent one. The analysis of the simple slopes also confirmed that when users possess high competency, technical and operational improvements have a far larger impact than technical improvements.

V. DISCUSSION

This research assessed the joint impact of technical, operational, and human subsystems on Biomedical Imaging Integration Performance in a high-volume tertiary hospital. The conversation, informed by the new systems-driven framework, connects the current empirical findings with GST, Workflow Theory, Database Management Theory, and the Technology Acceptance Model (TAM). The findings confirm that imaging integration is not just the result of discrete technical improvements but is rather the result of the synergy between system subsystems as they work together.

Integration Performance is Rooted in Technical Factors. Results indicate that System Integration and Database Management are the two technical factors, and significant and strong predictors of Integration Performance. System Integration was the single strongest predictor (β=0.46), confirming that interoperable, stable and real-time data exchange is the core of imaging operations. This is concordant with previous studies highlighting the relationship between PACS–RIS–HIS integration quality and radiology productivity and diagnostic processing. Database Management also had significant effect (β = 0.39) which highlights the need for query optimization, indexing, storage design, and data integrity in handling high-volume imaging. These results are consistent with Database Management Theory, which suggests that the performance of the system is highly dependent on the performance of the base data structures. Collectively, these results confirm the technical nature of the new framework and validate GST's argument that technical subsystems make up the structural underpinning of other subsystems.

Workflow Efficiency as an Operational Subsystem Influencing Performance. Workflow Efficiency, as an operational factor in the new Framework, was also a significant predictor of Integration Performance (β = 0.31). This result shows that despite good technical infrastructure, the coordination and organization of workflows, sequencing of tasks, communication practices and automation are still extremely important factors of performance of the system. The moderate variability (M=3.97, SD=0.62) in the Workflow Efficiency scores indicates that operational processes are more affected by human factors, workload variation, and departmental integration than hardware features. This is consistent with Workflow Theory, which posits that operational bottlenecks are likely to be created by human-led rather than systematic processes. The findings underscore the importance of workflow redesign, automation and cross-departmental coordination when integrating with technology upgrades.

The human factor of user competence as moderator. One of the main implications is the moderation effect of User Competency as a moderator variable. The moderation analysis found that User Competency also potentiated the impact of the two main features:

Database Management → Integration Performance (p = .018)

Workflow Efficiency → Integration Performance (p = .006)

but not System Integration.

- *This Indicates that:*

Technical database enhancements are much more effective when users are highly competent and use the tools for their workflow. Interoperability is a system-level technical function and is not dependent on how you use it; therefore, users of every skill level consistently benefit from its advantages. These results are consistent with Technology Acceptance Model (TAM) findings that user capacity and perceived ease of use will impact system performance. They also further uphold GST's notion that the contribution of human subsystems can amplify or inhibit performance for technical and operational subsystems.

Inter-dependence between Technical, Operational and Human Subsystems. Taken together, the findings are compelling in favor of the new systems-driven scheme. The strong interconnection between variables and moderation of User Competency suggests that imaging integration performance is a function of dependencies, not independent parts. At large, GST contends that subsystems within a complex environment need to be optimized in concert.

- *The Findings Confirm this:*

High performance cannot be ensured by technical enhancements alone. To operate, the system can only be coordinated and aligned with operational workflows. The extent to which the transfer of technical and operational improvements to performance improvements is also governed by human competency. This supports an institution of holistic governance like a PACS–RIS–HIS Integration Committee to prevent technical decision-making in the absence of operational and human impact.

- *Comparison with Existing Literature:*

The results are in agreement with prior studies which revealed that:

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- ✓ Imaging efficiency hinges on interoperability and database performance.
- ✓ Workflow bottlenecks reduce radiology productivity.
- ✓ User competence impacts system usage and error rates.

- *On the Other Hand, this Research Adds to Our Knowledge by:*

- ✓ Better separating technical and operational factors.
- ✓ Quantitatively demonstrating the moderating impact of user competency.
- ✓ The application of GST to explain the effect of subsystem interactions on integration performance.

This places the study as a valuable contribution to health informatics research, namely to the high-volume tertiary hospitals in the Middle East.

- *Implications for Practice. Hospitals Should:*

- ✓ Prioritize interoperability and optimization of databases as core investments.
- ✓ Reconsider workflows based on Lean and automation.
- ✓ Increase user competence through training and certification.
- ✓ Develop cross-departmental governance to orchestrate subsystem interdependencies.

Such implications have a direct basis for the revised framework and result in practical recommendations to enhance integration performance of imaging.

Thereby the Biomedical Imaging Integration Performance is proven via the analysis to be a function of technological power, operational efficiency and human talent; operating from an integrated part that has synergy with subsystems that are interdependent. The data strongly support the updated framework, and the results support GST's fundamental tenet: System performance is achieved by the seamless interconnectedness of all the subsystems and is not derived by isolated improvement.

The system-oriented framework which underlines the need to understand collaboration of technical, operational and human subsystems in the biomedical imaging environment, underpins the present results. The variables are categorized by different dimensions in this model to fit their theoretical function and functional features. System Integration and Database Management fall into the Technical Factors category; they are those structural and technological underpinnings that allow PACS, RIS, and HIS to work together effectively. These elements include interoperability standards, interface stability, data synchronization, database architectural considerations — all factors that are intrinsically technological. Workflow Efficiency on the other hand is an Operational Factor and not a technical one. Workflow Efficiency refers to the synchronization of work activities, communication styles, process flow, and departmental procedures that determine how imaging is performed. It is influenced by structure of workflow through routine, staff interaction and process design, not by hardware or software architecture.

Re-classification of Workflow Efficiency as an operational construct makes the theoretical contributions consistent with that published on workflow theory and health informatics. User Competency is proposed as a Moderating Factor—the knowledge, skills, and competencies of system users can contribute to either the enhancement or loss of effects related to the technical and operational systems. Advanced users are therefore more proficient in working with systems, decreasing errors and improving workflows that can serve to enhance the technical and operational benefits of changes. Lastly, the Performance of Biomedical Imaging Integration is the Outcome Variable and reflects the positive effect of PACS–RIS–HIS interoperability for clinical workflow, data accuracy and reliability of the system. This conceptual structure is consistent with the systems-driven view of the study which argues that integration performance is produced by coordinated operations of technical, operational, and human subsystems.

➢ *Limitations of the Study*

While this work is informative in informing PACS–RIS–HIS integration within a high-volume tertiary hospital, several limitations must be noted. The study, therefore, employed a relatively small sample size (N = 40) that included exceptionally dedicated professionals involved in the imaging workflow, which might have diminished statistically the power of regression and moderation analyses. In this sense, the results should be cautiously interpreted, in particular with respect to the stability of interaction effects in moderation modeling. Second, the respondent profile is indicative of a professional population working in a technologically advanced, resource-rich setting. Dr. Sulaiman Al-Habib Hospital is a high-volume tertiary care institution with mature digital infrastructure, excellent IT support and well-established imaging informatics practices. Consequently, findings may not be fully applied to smaller hospitals, rural facilities, or clinics with limited budgets, older PACS/RIS/HIS systems, or less specialized staff. Third, the study was limited to self-reported perceptions as opposed to objective system performance measures such as server logs, DICOM transaction times, or real-time workflow analytics. Although perceptions of user experiences are vital to understand the state of the art, they might not describe the complete technical aspect of integration performance. Finally, it is not possible to infer causality as it was a cross-sectional design. Longitudinal or mixed-methods studies may inform how technical, operational, and human factors transition over time and interact during system upgrades or workflow changes. Nevertheless, the study provides important insights by

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illustrating the relationship among technical, operational, and human subsystems and their impacts on imaging integration performance in a high-volume tertiary care environment.

This study provides a GST-Aligned explanation of the Committee's function. On the basis of General Systems Theory, this recommendation makes clear why an Imaging Informatics Governance Committee is essential. GST emphasizes that complex systems—such as PACS–RIS–HIS environments—function through interdependent subsystems whose operating ability depends on coordination at runtime.

The technical subsystem (system integration and database management), the operational subsystem (workflow efficiency), and the human subsystem (user competency) were shown to influence each other and not operate in isolation in this study. The proposed committee is the entity which undertakes the management of these interdependencies. This committee sets out to establish that decisions made in technical areas—including changes to the database, modifications in interfaces, or upgrading the PACS—are never made without input from radiology technologists and frontline personnel who carry out the operation as well as human side of the organization. This avoids technically sound decisions accidentally disturbing workflow patterns, introducing cognitive load, or reducing user efficiency. The committee embodies the principle of GST: changes in one subsystem inherently affect the others. By institutionalizing cross-functional consultation, it ensures that:

- The technological decisions are measured in terms of how they impact operations.
- Workflow redesigns consider technical feasibility.
- System configuration and training options are shaped by user proficiency requirements according to the user competency level.

In this manner, the committee is the coordinating element of the team that balances, minimizes side effects, keeps us all in step with system equilibrium, and leads toward ongoing improvement of imaging integration performance.

VI. CONCLUSION

The performance of PACS–RIS–HIS integration was assessed in a systems-driven framework, delineating technical (System Integration and Database Management), operational (Workflow Efficiency), and human (User Competency as moderator) factors. The refined system also helped explain more clearly how these subsystems connect to affect total integration in a large tertiary hospital. This study found that System Integration, Database Management, and Workflow Efficiency independently and in combination affect Integration Performance and also confirmed that imaging ecosystems require a solid combination of a technical infrastructure and well-coordinated operational processes. Of these, System Integration was the most significant predictor and emphasized the importance of interoperability standards, interface stability, and real-time data exchange in clinical workflows. In addition, moderation analysis showed that User Competency enhances Database Management and Workflow Efficiency, which is an indicator that even the best-designed systems must not be without skills-based users to work well.

It complements the human-centered aspect of the framework and is consistent with the Technology Acceptance Model (TAM) that highlights the need for users to be more capable in order to derive benefits from the system. Grounded in General Systems Theory (GST), the authors discovered that imaging integration, in addition to independent technical improvements, was due to cooperative interactions between specific technical, operational, and human subsystems. "If there is a strong improvement in one part… there is a large effect on the others and the importance of holistic governance, cross-departmental collaboration." Overall, the paper identifies that to best achieve PACS–RIS–HIS integration a fine tuning strategy that not only supports technical architecture enhancement but that also optimizes operational workflows and boosts user competence is required.

Understanding systems from that systems-driven lens gives a more holistic perspective on integration performance, supporting hospitals that want to innovate with technologies for contemporary imaging environments that enable patient-centered care. "The conclusion with the updated framework now reiterates that integration performance is determined by the interaction of technical, operational, and human factors. System Integration and Database Management are the technical underpinning, Workflow Efficiency is the operational component, and User Competency moderates the system efficacy. This study supports General Systems Theory of integrated imaging: the integration of imaging is a systems problem and not a single-component issue. So hospitals need to optimize these three subsystems in conjunction to make a meaningful contribution."

RECOMMENDATIONS

➢ *Technical Advice (System Integration & Database Management):*

Aligned to the "Technical Factors" in the updated specification.

- *Enhance Interoperability (Integrate the Different Systems):*

Standardize the implementation of DICOM, HL7, and FHIR across all modalities. Implement API/middleware performance monitoring to identify integration issues early. Implement redundant interface

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engines to prevent RIS–PACS–HIS downtime. Carry out quarterly stress tests for integration resilience assessment.

- *Data Architecture with an Eye to Database Management:*

Use index optimization and query tuning for high-volume imaging tables. Load balancing across PACS/RIS database servers for peak traffic partitioning. Use asynchronous data processing (message queues) for DICOM routing at high throughput. Implement tiered storage architecture (SSD → RAID → cloud/object storage). Use real-time database performance dashboards for proactive monitoring.

✓ *Why These Matter:*

These interventions directly impact the technical subsystem, which GST claims is foundational to the performance of the entire imaging ecosystem.

➢ *Operational Recommendations (How Effectively a Workflow Applies).*

Based on the new "Operational Factor" in the modified framework.

- *Use Lean Principles to Redesign Imaging Processes:*

Map existing workflows to uncover bottlenecks (routing delays, manual steps, etc.). Implement automation for the tasks that repeat (auto-routing, auto-prefetching). Standardize imaging protocols across modalities to eliminate variability. Enhance inter-departmental communication (radiology, IT, nursing).

- *Implement Real-Time Workflow Monitoring:*

Monitor turnaround time (TAT), queue length, routing delays. Create dashboards to notify employees when workflow thresholds have been crossed. Use workflow analytics for PACS/RIS that allows the project to improve over a period of time.

✓ *Why These Matter:*

Workflow Efficiency is an operational subsystem and according to GST, operational processes need to be aligned with technical capabilities to avoid a bottleneck at a systems level.

➢ *Recommendations with a Human-Centered Approach (User Skill as Guide):*

Aligned with "Moderating Factor" in a revised shape of the framework.

- *Strengthen User Competence with Structured Training:*

Train technologists, radiologists and IT staff role-specific training for new roles. Conduct simulation-based training for the new PACS/RIS features. Provide certification pathways for PACS/RIS administrators. Use competency assessments every 6–12 months.

- *Encourage Collaboration Between Functions:*

Set up a PACS–RIS–HIS Integration Committee (IT + Radiology + Clinical Ops). Use operational input; never make technical decisions without having some input to go on. You should apply GST considerations and analyze the impact of changes in one subsystem on others.

✓ *Why These Matter:*

With regard to moderation results, we found that Database Management and Workflow Efficiency only strongly predict Integration Performance when User Competency is high. Hence, developing competency magnifies the influence of technical and operational changes. Governance Recommendations (GST-Driven Interdependency Management). In line with the systems-driven nature of your study.

➢ *Create a System-Led Integration Governance Model.*

Form a cross-departmental Integration Committee. Require joint approval of PACS/RIS/HIS changes. Use GST to confirm interdependencies before making the upgrades. Assess quarterly system performance, workflow metrics and user feedback.

➢ *Introduce, or Adopt, "No-Silo Decision-Making" Policy.*

IT cannot change databases, interfaces, or APIs without referring to radiology operations. Radiology will not be able to change workflows without consulting IT and PACS administrators. All decisions should relate to the technical → operational → human side. Why this matters:

➢ *GST Points Out that There Can be no Independent Maximization of Subsystems.*

Thus this governance model ensures that system-wide optimization, not isolated remedies, work. The recommendations were to align with the updated conceptual framework by separating technical, operational, and human-centered interventions. Technical recommendations now concern interoperability and database architecture, operational recommendations address workflow efficiency, while human-centered recommendations enhance user competency, which our moderation analysis showed is essential for maximizing system performance. Lastly, a GST-aligned governance model ensures that interdependencies across subsystems are managed holistically instead of in silos."

➢ *Granular Technical Recommendations.*

In light of the results of this systems-related examination, some recommendations to improve PACS–RIS–HIS integration performance are suggested. These guidelines concentrate on improving the technical, operational and human subsystems that work together and shape biomedical imaging routines. The detailed, engineering grade interventions which are recommended based on health informatics best practice are as follows.

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- *Technical Recommendations*

Use Load Balancing between the PACS and Database Servers. High-volume imaging times can overburden single servers, causing slow image collection and delayed image retrieval. A load balancing system should be used to distribute DICOM and database traffic on multiple nodes. Methods such as round-robin, least-connection algorithms, and active failover nodes can stabilize system performance and reduce latency.

Introduce Asynchronous Data Processing for Non-Critical Tasks. Much PACS/RIS activity does not demand real-time execution. Utilization of asynchronous message queues is encouraged for prefetching prior studies, generating thumbnails, archiving, and non-urgent routing. Message brokers (e.g., RabbitMQ, Kafka) can take some of these workloads out of real-time processing pipelines and, at busy times, improve responsiveness.

Optimize Database Indexing and Query Execution Plans. RIS/PACS delays in many cases originate from database inefficiencies. Composite indexes for high-frequency fields (MRN, accession number, modality, and date), query execution plans, and large table partitioning will greatly improve the speed at which queries are performed. If metadata is frequently accessed, enable in-memory caching to minimize database load.

Enable Multithreaded DICOM Processing Pipelines. When modalities send large numbers of images to DICOM receivers, single-threaded DICOM receivers may become bottlenecks. System scalability in high-volume periods and backlog prevention are enabled by setting up multithreaded C-STORE and C-MOVE operations as well as using dynamic thread pools.

Implement Tiered Storage Architecture. Imaging data does not all need the same level of performance. A tiered storage model—SSD/NVMe for active studies, RAID HDD for recent studies, and object/cloud storage for long-term archives—will be a practical approach to strike a balance between speed and cost and enhance retrieval times of current imaging workloads.

Implement Intelligent Prefetching and Auto-Routing Rules. Automated prefetch of prior studies according to scheduled appointments and rules-based routing to radiologists can help minimize the manual workload and maintain continuity of workflow. AI-based routing could also optimize prioritization more efficiently and minimize turnaround time.

Strengthen HL7/DICOM Interface Monitoring. Integration failures often occur silently and accumulate over time. To detect HL7 acknowledgment failures, DICOM association drops, RIS–PACS mismatches, and missing demographic data, tools should be utilized for real-time interface monitoring. Automated alerts will help avoid workflow disruptions and mitigate manual correction processes.

Implement Database Replication and High-Availability Clustering. To maintain the system, particularly at peak times, it's critical to build active-active or active-passive database clusters. Automatic failover and real-time replication facilities help mitigate downtime and single-point failure risks.

Introduce Real-Time Performance Dashboards. Operational visibility is a must for proactive optimization. Dashboards shall monitor the DICOM queue length, database latency, HL7 throughput, PACS node resource consumption, and network bandwidth. Immediate detection of bottlenecks is critical to early intervention before clinical workflows are affected.

Conduct Regular Stress Testing and Capacity Planning. Utilizing DICOM ingestion tests, RIS worklist load tests, and database concurrency tests to simulate peak imaging loads will reveal system weaknesses. Scheduled failover drills and capacity planning exercises ensure the system remains resilient as imaging volumes grow.

- *Operational Recommendations*

Standardize Imaging Workflow Protocols. Well-defined, consolidated protocols for scheduling, acquisition, reporting, and distribution will lower variability and optimize workflow.

Strengthen Interdepartmental Coordination. Routine coordination meetings among radiology, IT, biomedical engineering, and clinical departments will foster alignment and expedited resolution of workflow bottlenecks.

- *Human Resource Recommendations*

Enhance User Competency Through Structured Training. Competency-based training programs should be implemented to ensure users understand system functionalities, workflow requirements, and troubleshooting procedures.

Establish Continuous Skills Assessment. Ongoing evaluations can identify skill gaps while ensuring users keep up with systems as they evolve.

- *Policy and Governance Recommendations*

Develop an Imaging Informatics Governance Committee. A multidisciplinary committee may supervise integration performance, system upgrades, workflow redesign, and data governance.

Implement Data Quality and Interoperability Standards. Policies should enforce consistent use of patient identifiers, modality worklist compliance, and standardized coding practices.

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APPENDICES

Appendix A.

Survey Instrument

Title: Biomedical Imaging Application Integration Survey Objective: To measure perceived system integration, database management, workflow efficiency, and integration performance. Give answers to the following statements based on your response (in the following format):

1 -- Strongly Disagree 2 -- Disagree 3 -- Neutral 4 -- Agree 5 -- Strongly Agree.
SURVEY QUESTIONNAIRE (40-ITEM LIKERT SCALE).
Scale: 1 – Strongly Disagree 2 – Disagree 3 – Neutral 4 – Agree 5 – Strongly Agree.

➢ *System Integration Factors (10 Items).*

1. PACS and RIS transfer data more precisely and consistently.
   1 – Strongly Disagree 2 – Disagree 3 – Neutral 4 – Agree 5 – Strongly Agree.

2. Imaging systems promptly display HIS updates.
   1 – Strongly Disagree 2 – Disagree 3 – Neutral 4 – Agree 5 – Strongly Agree.

3. The PACS-RIS-HIS integration is maintained for seamless workflow.
   1 – Strongly Disagree 2 – Disagree 3 – Neutral 4 – Agree 5 – Strongly Agree.

4. DICOM standards are uniformly enforced on all devices.
   1 – Strongly Disagree 2 – Disagree 3 – Neutral 4 – Agree 5 – Strongly Agree.

5. HL7 messaging is dependable and error-free.
   1 – Strongly Disagree 2 – Disagree 3 – Neutral 4 – Agree 5 – Strongly Agree.

6. Middleware and API connections work without frequent failures.
   1 – Strongly Disagree 2 – Disagree 3 – Neutral 4 – Agree 5 – Strongly Agree.

7. Imaging requests are smoothly communicated between systems.
   1 – Strongly Disagree 2 – Disagree 3 – Neutral 4 – Agree 5 – Strongly Agree.

8. All alerts and notifications are synchronized across platforms.
   1 – Strongly Disagree 2 – Disagree 3 – Neutral 4 – Agree 5 – Strongly Agree.

9. Integration problems are quickly resolved by the team of IT staff.
   1 – Strongly Disagree 2 – Disagree 3 – Neutral 4 – Agree 5 – Strongly Agree.

10. General interoperability meets clinical requirements.
   1 – Strongly Disagree 2 – Disagree 3 – Neutral 4 – Agree 5 – Strongly Agree.

11. Database queries can be quick and efficient during busy periods.
   1 – Strongly Disagree 2 – Disagree 3 – Neutral 4 – Agree 5 – Strongly Agree.

12. Indexing and processing enhance the retrieval time.
   1 – Strongly Disagree 2 – Disagree 3 – Neutral 4 – Agree 5 – Strongly Agree.

13. Large imaging datasets support storage architecture.
   1– Strongly Disagree 2 – Disagree 3 – Neutral 4 – Agree 5 – Strongly Agree.

14. The backup of databases is made consistently and reliably.
   1 – Strongly Disagree 2 – Disagree 3 – Neutral 4 – Agree 5 – Strongly Agree.

15. All imaging systems adhere to the same data consistency.
   1 – Strongly Disagree 2 – Disagree 3 – Neutral 4 – Agree 5 – Strongly Agree.

16. Database downtime is minimal.
    1 – Strongly Disagree 2 – Disagree 3 – Neutral 4 – Agree 5 – Strongly Agree.

17. An interfacing database format is integrated with external systems.
    1 – Strongly Disagree 2 – Disagree 3 – Neutral 4 – Agree 5 – Strongly Agree.

18. Query optimization techniques are effectively implemented.
    1 – Strongly Disagree 2 – Disagree 3 – Neutral 4 – Agree 5 – Strongly Agree.

19. Database logs contribute to quick detection of system issues.
    1 – Strongly Disagree 2 – Disagree 3 – Neutral 4 – Agree 5 – Strongly Agree.

20. Overall database performance supports imaging workflow.
    1 – Strongly Disagree 2 – Disagree 3 – Neutral 4 – Agree 5 – Strongly Agree.

➢ *Workflow Efficiency (10 Items)*

21. Imaging requests are handled without excessive delay.
    1 – Strongly Disagree 2 – Disagree 3 – Neutral 4 – Agree 5 – Strongly Agree.

22. Fast and consistent image retrieval is the answer.
    1 – Strongly Disagree 2 – Disagree 3 – Neutral 4 – Agree 5 – Strongly Agree.

23. Imaging duties are performed without the system making successive errors.
    1 – Strongly Disagree 2 – Disagree 3 – Neutral 4 – Agree 5 – Strongly Agree.

24. Workflow interruptions are minimal.
    1 – Strongly Disagree 2 – Disagree 3 – Neutral 4 – Agree 5 – Strongly Agree.

25. The system reduces manual data entry.
    1 – Strongly Disagree 2 – Disagree 3 – Neutral 4 – Agree 5 – Strongly Agree.

26. Imaging turnaround time is acceptable.
    1 – Strongly Disagree 2 – Disagree 3 – Neutral 4 – Agree 5 – Strongly Agree.

27. The system facilitates patient movement through radiology.
    1 – Strongly Disagree 2 – Disagree 3 – Neutral 4 – Agree 5 – Strongly Agree.

28. System automation reduces staff workload.
    1 – Strongly Disagree 2 – Disagree 3 – Neutral 4 – Agree 5 – Strongly Agree.

29. The workflow is predictable and consistent.
    1 – Strongly Disagree 2 – Disagree 3 – Neutral 4 – Agree 5 – Strongly Agree.

30. Overall workflow efficiency is satisfactory.
    1 – Strongly Disagree 2 – Disagree 3 – Neutral 4 – Agree 5 – Strongly Agree.

➢ *Integration Performance (10 Items)*

31. The system supports accurate clinical decision-making.
    1 – Strongly Disagree 2 – Disagree 3 – Neutral 4 – Agree 5 – Strongly Agree.

32. Imaging data is always available when needed.
    1 – Strongly Disagree 2 – Disagree 3 – Neutral 4 – Agree 5 – Strongly Agree.

33. The system improves patient care quality.
    1 – Strongly Disagree 2 – Disagree 3 – Neutral 4 – Agree 5 – Strongly Agree.

34. Integration reduces radiology department delays.
    1 – Strongly Disagree 2 – Disagree 3 – Neutral 4 – Agree 5 – Strongly Agree.

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35. The system enhances communication among clinical staff.
    1 – Strongly Disagree 2 – Disagree 3 – Neutral 4 – Agree 5 – Strongly Agree.

36. Integration reduces errors in imaging workflows.
    1 – Strongly Disagree 2 – Disagree 3 – Neutral 4 – Agree 5 – Strongly Agree.

37. The system is reliable during high-volume periods.
    1 – Strongly Disagree 2 – Disagree 3 – Neutral 4 – Agree 5 – Strongly Agree.

38. Users are satisfied with system performance.
    1 – Strongly Disagree 2 – Disagree 3 – Neutral 4 – Agree 5 – Strongly Agree.

39. Integration contributes to overall hospital efficiency.
    1 – Strongly Disagree 2 – Disagree 3 – Neutral 4 – Agree 5 – Strongly Agree.

40. The imaging integration system meets organizational expectations.
    1 – Strongly Disagree 2 – Disagree 3 – Neutral 4 – Agree 5 – Strongly Agree.

Appendix B.

Conceptual Framework

And this is the revised, remediated, defensible framework with clean separation that is clearly separated. Technical Factors. Operational Factors. Moderating Factor. Outcome Variable. Framework for improvement (Amended). Technical vs. Operational Dimensions Clearly Distinguished.

➢ *Description of Framework Elements*

- Technical Factor System Integration Technical Interoperability, DICOM/HL7, API performance.
- Technical Factor Database Management Technical Query speed, indexing, storage, data integrity.
- Operational Factor Workflow Efficiency Operational Task flow, coordination, automation, delays.
- Moderating Factor User Competency Human Skills, training, system familiarity.
- Outcome Variable Integration Performance System Outcome Reliability, speed, accuracy, satisfaction.

Category	Variable	Nature	Description
Technical Factor	System Integration	Technical	Interoperability, DICOM/HL7, API performance.
Technical Factor	database Management	Technical	Query speed, indexing, storage, data integrity.
Operational Factor	Workflow Efficiency	Human	Skills, training, system familiarity.
Moderating Factor	Integration Performance	System Outcome	Reliability, speed, accuracy, satisfaction