

Optimizing Digital Radiology Workflows: A Quantitative Correlation Analysis Between PACS Utilization Efficiency and Clinical Throughput Performance in Tertiary Diagnostic Imaging Departments

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Abstract

This study examined the relationship between Picture Archiving and Communication System (PACS) utilization efficiency and clinical throughput performance in tertiary diagnostic imaging departments in Batangas, Philippines, to identify significant predictors of operational efficiency and propose workflow optimization strategies. Guided by a conceptual framework linking digital system efficiency with clinical performance, the study employed a quantitative, non-experimental correlational research design involving 43 radiology personnel selected through purposive sampling and total enumeration of eligible respondents. Data were collected using a validated, structured questionnaire and analyzed through descriptive statistics, Pearson and Spearman correlation, and multiple linear regression. Findings revealed moderately high PACS utilization efficiency ($M = 3.48$) and high clinical throughput performance ($M = 3.80$). A significant positive relationship was established between PACS utilization efficiency and clinical throughput performance (Pearson $r = 0.581$, $p < .001$; Spearman $\rho = 0.495$, $p < .001$). Regression analysis indicated that PACS utilization indicators explained 38.4% of the variance in clinical throughput performance ($R^2 = 0.384$, $p < .001$), with system downtime and error frequency emerging as the only statistically significant predictor ($\beta = 0.407$, $p = 0.005$). These findings emphasize the importance of system reliability in supporting efficient diagnostic imaging operations. Recommended strategies include preventive maintenance, infrastructure enhancement, system integration, improved accessibility, staff training, and workflow management. The study supports Sustainable Development Goal (SDG) 3 (Good Health and Well-Being) and SDG 9 (Industry, Innovation and Infrastructure) by informing improvements in diagnostic service efficiency and digital healthcare infrastructure. It contributes to technological, institutional, and healthcare sustainability by providing evidence to guide reliable radiology operations, resource management, and continuous service improvement.

Keywords: Digital Radiology; Healthcare Sustainability; Image Retrieval Speed; PACS Utilization Efficiency; Patient Flow; Radiology Workflow; System Downtime; Workflow Optimization

1. Introduction

The digital transformation of healthcare has significantly reshaped diagnostic radiology, with Picture Archiving and Communication Systems (PACS) becoming essential for medical image storage, retrieval, interpretation, and communication. Beyond image management, PACS supports clinical workflows that influence diagnostic efficiency, reporting timeliness, and patient service delivery. However, its operational effectiveness depends on system reliability, interoperability, technical support, and user competency (Shah et al., 2022; Bharadwaj et al., 2024). This study examines the relationship between PACS utilization efficiency and clinical throughput performance in tertiary diagnostic imaging departments in Batangas, Philippines, to identify significant predictors of operational performance and develop evidence-informed workflow optimization strategies.

Digital radiology systems have transformed healthcare operations by facilitating the electronic storage, transmission, and accessibility of diagnostic images. PACS enables healthcare professionals to retrieve and interpret imaging examinations while supporting communication among radiologists, radiologic technologists, and referring physicians. Integration with Radiology Information Systems (RIS), Hospital Information Systems (HIS), and Electronic Medical Records (EMR) is important for coordinated clinical operations (Shah et al., 2022; Tejani et al., 2024). Despite these advantages, technological interruptions, inefficient data retrieval, fragmented workflows, and inadequate system integration remain operational challenges. Bharadwaj et al. (2024) identified multiple inefficiencies throughout radiology workflows, emphasizing the importance of evaluating digital technologies according to usability, integration, and demonstrated operational benefits. Similarly, Becker et al. (2024) demonstrated how automated processes can reduce repetitive tasks and support more efficient radiology workflows. Clinical throughput performance reflects how effectively diagnostic imaging departments manage patient demand, examination completion, waiting times, and diagnostic reporting. Consequently, evaluating PACS requires examining not only its technical functions but also its association with operational service performance (Law et al., 2024).

Recent literature highlights three interconnected themes concerning PACS utilization and radiology workflow performance: digital information accessibility, operational workflow optimization, and technological reliability. First, digital information accessibility and interoperability are essential to radiology operations. Shah et al. (2022) explained that modern imaging informatics depends on the coordinated exchange of information among PACS, RIS, HIS, and electronic health records. Tejani et al. (2024) further emphasized that standards-based interoperability facilitates information exchange across radiology systems and reduces the operational complexity of integrating digital technologies. Second, workflow automation and communication efficiency contribute to more coordinated imaging services. Lee et al. (2023) examined a PACS-integrated communication function and demonstrated its usefulness in facilitating communication among radiologists and radiographers. Meanwhile, Law et al. (2024), in a two-year cohort study involving 232,022 examinations, found that integrated automatic examination assignment reduced interruptions and improved reporting turnaround times. These findings illustrate the operational value of coordinated digital workflows. Third, system reliability, usability, and staff competency remain important considerations in technology adoption. Bharadwaj et al. (2024) identified integration, usability, and operational effectiveness as critical criteria in evaluating radiology workflow solutions. In the Philippine context, Canguit and Sison (2025) reported favorable perceptions of PACS diagnostic efficiency among radiologic technologists while identifying challenges involving technological adaptation, communication, and training. Collectively, these studies suggest that PACS efficiency cannot be evaluated through image storage and retrieval capabilities alone. Technical reliability, information accessibility, communication, and workflow organization must also be considered in assessing diagnostic imaging performance.

Globally, digital health transformation has become an important strategy for improving the accessibility, efficiency, and resilience of healthcare services. The World Health Organization (2025) reaffirmed this direction through its *Global Strategy on Digital Health 2020–2027*, emphasizing coordinated digital health development, interoperability, and sustainable healthcare systems. Nationally, the Philippine healthcare sector continues to pursue digital integration and improved health information management. The Philippine Health Insurance Corporation (2024) reported the launch of the National Health Data Repository and Philippine Core Data for Interoperability, emphasizing standardized health information exchange and improved healthcare coordination. Philippine research also demonstrates the relevance of studying diagnostic imaging workflows. Lim et al. (2023) examined imaging utilization and operational changes in a two-site tertiary academic hospital setting using imaging records and PACS data. Furthermore, Canguit and Sison (2025) investigated diagnostic efficiency and PACS-related challenges among radiologic technologists in a Philippine hospital, highlighting the relevance of technical competency and workflow adaptation. Within Batangas, the present study focuses on selected tertiary diagnostic imaging departments where PACS supports routine clinical operations. Examining the relationship between system utilization efficiency and clinical throughput performance provides institution-specific evidence relevant to radiology service management and digital healthcare improvement.

This study adopts a systems-oriented conceptual framework in which PACS utilization efficiency is associated with the operational performance of diagnostic imaging departments. The framework recognizes that healthcare technology functions within an interconnected environment involving technical infrastructure, information exchange, clinical processes, and healthcare personnel. Shah et al. (2022) described imaging informatics as an integrated environment in which medical images, clinical information, and diagnostic reporting depend on coordinated information systems. Similarly, Tejani et al. (2024) emphasized standards-based interoperability as a foundation for efficient radiology information exchange, while Bharadwaj et al. (2024) highlighted the importance of assessing digital solutions according to their operational effectiveness. Within this framework, PACS Utilization Efficiency serves as the independent variable, measured through four dimensions: system usage time, image retrieval speed, reporting turnaround time, and system downtime and error frequency. Clinical Throughput Performance serves as the dependent variable, assessed through the number of patients served, patient waiting time, examination completion rate, and report release time. The framework proposes that differences in PACS utilization efficiency are associated with differences in clinical throughput performance. It also recognizes that individual system-related factors may vary in their predictive contribution to throughput outcomes. Because the study uses a non-experimental correlational design, these relationships are interpreted as statistical associations rather than evidence of causation.

Recent studies have investigated several dimensions of radiology digitalization, including PACS-integrated communication (Lee et al., 2023), automated examination assignment (Law et al., 2024), workflow optimization applications (Bharadwaj et al., 2024), and diagnostic efficiency among radiologic technologists (Canguit & Sison, 2025). Although these investigations provide important insights, they address different aspects of radiology performance. Additional context-specific evidence is needed to understand how multiple dimensions of PACS utilization efficiency relate collectively and individually to clinical throughput performance, particularly in tertiary diagnostic imaging departments in Batangas. Accordingly, the present study examines the relationship between PACS utilization efficiency and clinical throughput performance and determines whether system usage time, image retrieval speed, reporting turnaround time, and system downtime and error frequency significantly predict throughput outcomes. The findings are intended to provide an empirical basis for proposing strategies related to system reliability, infrastructure improvement, interoperability, staff competency, and workflow management.

The study is aligned primarily with Sustainable Development Goal 3 (Good Health and Well-Being) and Sustainable Development Goal 9 (Industry, Innovation and Infrastructure). SDG 3 – Good Health and Well-Being. The research addresses operational factors associated with timely and efficient diagnostic imaging services. Examining PACS utilization and clinical throughput can inform improvements in examination processing, patient waiting times, and report availability. These operational improvements support the broader objective of strengthening accessible and responsive healthcare services (World Health Organization, 2025). SDG 9 – Industry, Innovation and Infrastructure. The study emphasizes the importance of dependable digital infrastructure and integrated information systems in modern healthcare institutions. PACS utilization, technical reliability, and workflow optimization reflect the role of digital innovation in supporting resilient institutional operations (Shah et al., 2022; Tejani et al., 2024). Through these connections, the research contributes evidence relevant to healthcare service efficiency and the responsible integration of technological infrastructure. Its contribution concerns operational improvement rather than directly measured patient health outcomes or SDG-level impacts.

The study contributes to multidisciplinary sustainability through the interconnected domains of healthcare, technology, institutional management, and workforce development. From a healthcare sustainability perspective, understanding the relationship between PACS efficiency and clinical throughput can support the continued provision of timely diagnostic services and more effective patient-flow management. From a technological sustainability perspective, the study highlights the operational importance of system reliability, interoperability, maintenance, and accessible digital imaging information. These considerations are consistent with contemporary recommendations for integrated healthcare information systems (Shah et al., 2022; Tejani et al., 2024). From an institutional and socio-economic sustainability perspective, identifying workflow inefficiencies can guide more informed decisions concerning technological investments, resource allocation, and departmental operations. Bharadwaj et al. (2024) emphasized the importance of evaluating workflow technologies in relation to operational benefits and institutional requirements. Finally, the study supports workforce and professional development sustainability by recognizing the importance of technical competency, continuous training, and adaptation to changing digital environments, as highlighted by Canguit and Sison (2025). Overall, the study provides an evidence-informed basis for improving digital radiology operations while supporting the long-term efficiency, reliability, and adaptability of tertiary diagnostic imaging departments.

2. Material and methods

2.1 Research Design

The study utilized a quantitative, non-experimental correlational research design to determine the relationship between PACS utilization efficiency and clinical throughput performance without manipulating the study variables. This approach enabled the assessment of the strength and direction of relationships between system efficiency indicators and operational outcomes in actual radiology settings.

2.2 Locale of the Study

The study was conducted in selected tertiary hospitals in Batangas, Philippines, particularly within their diagnostic imaging departments. These institutions were selected because of their advanced imaging capabilities, high patient volumes, and established utilization of PACS, providing an appropriate setting for examining digital radiology workflow efficiency and clinical throughput performance.

2.3 Respondents of the Study

The respondents comprised 43 radiologic technologists, radiologists, and other diagnostic imaging personnel directly involved in routine PACS operations. Eligible participants were required to have at least six months of continuous PACS utilization to ensure sufficient familiarity with the system and its operational processes.

2.4 Sample and Sampling Procedure

The study employed purposive sampling to identify qualified radiology personnel with direct experience in PACS utilization. Total enumeration was subsequently applied within the selected departments by inviting all eligible personnel who met the inclusion criteria, resulting in 43 respondents. The sample size was considered in relation to Green's (1991) recommended regression sample-size formula, $N \geq 50 + 8m$, which yields 82 participants for four predictors. Although the actual sample was smaller than this benchmark, the study cited Hair et al. (2020) regarding the potential use of smaller samples in regression analysis when appropriate statistical assumptions and effect-size considerations are satisfied. The study proceeded with 43 eligible respondents from the selected departments.

2.5 Research Instrument

Data were collected using a structured, self-administered questionnaire designed to assess PACS utilization efficiency and clinical throughput performance. The instrument employed a five-point Likert scale ranging from 1 (Very Low) to 5 (Very High). PACS utilization efficiency was measured through system usage time, image retrieval speed, reporting turnaround time, and system downtime and error frequency. Clinical throughput performance was assessed through the number of patients served per day, patient waiting time, examination completion rate, and report release time. The questionnaire underwent content validation by experts in radiology and healthcare management to establish the relevance and clarity of its items.

2.6 Data Gathering Procedure

Permission to conduct the study was obtained from the administrators and department heads of the participating tertiary hospitals. Eligible respondents were informed about the study's objectives and the voluntary nature of their participation. The questionnaires were personally distributed to qualified radiology personnel and collected upon completion. Confidentiality, informed consent, and proper handling of research data were observed throughout the data collection process.

2.7 Data Analysis Techniques

Data were analyzed using descriptive and inferential statistical techniques. Cronbach's alpha was used to evaluate the internal consistency of the questionnaire, with a coefficient of 0.70 or higher established as the criterion for acceptable reliability. Means and standard deviations were computed to determine the levels of PACS utilization efficiency and clinical throughput performance. Pearson product-moment correlation (r) and Spearman rank-order correlation (ρ) were employed to examine the strength and direction of relationships between the study variables. Multiple linear regression was conducted to determine the predictive contributions of system usage time, image retrieval speed, reporting turnaround time, and system downtime and error frequency to clinical throughput performance. Model performance was evaluated using R , R^2 , adjusted R^2 , and the F-test, while standardized beta coefficients (β), t-values, and p-values were examined to identify significant predictors. The Durbin-Watson statistic was also reported to assess residual autocorrelation. All inferential analyses employed a significance level of $p < 0.05$.

2.8 Ethical Considerations

The study adhered to ethical standards for research involving human participants. Respondents were informed about the study's purpose, procedures, and their right to withdraw without penalty. Participation was voluntary, and confidentiality and anonymity were maintained. All collected information was used exclusively for academic and research purposes.

3. Results and Discussion

3.1 PACS Utilization Efficiency and Clinical Throughput Performance

3.1.1 PACS Utilization Efficiency

The overall PACS utilization efficiency obtained a mean of 3.48 (SD = 0.45), indicating a moderately high level of efficiency. Image retrieval speed recorded the highest mean (M = 3.67, SD = 0.69), followed by reporting turnaround time (M = 3.64, SD = 0.70) and system usage time (M = 3.37, SD = 0.56). System downtime and error frequency obtained the lowest mean (M = 3.25, SD = 0.71), indicating that technical interruptions remain an operational concern. These findings suggest that PACS generally supports efficient image retrieval, reporting, and daily radiology operations. However, system interruptions and technical errors may compromise workflow continuity. Shah et al. (2022) emphasized the importance of imaging informatics systems in facilitating medical image management and clinical information exchange. Similarly, Dhamija et al. (2022) highlighted the operational consequences of PACS downtime and the importance of maintaining alternative imaging access during disruptions. These studies support the need for reliable digital infrastructure to sustain efficient radiology services.

3.1.2 Clinical Throughput Performance

Clinical throughput performance obtained an overall mean of 3.80 (SD = 0.60), indicating a high level of operational efficiency. Examination completion rate registered the highest mean (M = 3.80, SD = 0.72), followed by report release time (M = 3.71, SD = 0.73) and patient waiting time (M = 3.56, SD = 0.69). Regarding patient volume, 48.84% of respondents reported serving 50–100 patients daily, 20.93% reported 101–200 patients, and 9.30% reported more than 200 patients. The findings indicate that participating diagnostic imaging departments generally maintain efficient examination completion and reporting processes. Nevertheless, patient waiting time remains an area for improvement. Law et al. (2024) demonstrated that integrating automated examination assignment with clinical scheduling systems significantly reduced radiology workflow interruptions and reporting turnaround times. Similarly, Bharadwaj et al. (2024) emphasized the importance of evaluating workflow technologies according to their operational effectiveness, integration, and usability. These findings support the relevance of coordinated scheduling and digital workflow management in improving radiology service efficiency.

3.2 Relationship Between PACS Utilization Efficiency and Clinical Throughput Performance

3.2.1 Correlation Between PACS Utilization Efficiency and Clinical Throughput Performance

Correlation analysis revealed a statistically significant positive relationship between PACS utilization efficiency and clinical throughput performance. Pearson's correlation coefficient was $r = 0.581$ ($p < .001$), while Spearman's rank-order correlation was $\rho = 0.495$ ($p < .001$). Both results indicate a moderate positive association between the study variables. These findings suggest that higher PACS utilization efficiency is associated with better clinical throughput performance. Efficient image retrieval, reporting processes, and system operations may support improved examination completion and patient management. Lee et al. (2023) demonstrated the usefulness of PACS-integrated communication functions in facilitating collaboration among radiology personnel. Similarly, Law et al. (2024) reported improved reporting efficiency following the integration of automated examination assignment with scheduling systems. Although these studies examined different operational outcomes, they support the importance of coordinated digital imaging workflows in radiology service delivery.

3.2.2 Predictive Influence of PACS Utilization Indicators

Multiple linear regression analysis revealed that PACS utilization indicators collectively demonstrated a statistically significant predictive relationship with clinical throughput performance ($R = 0.619$, $R^2 = 0.384$, adjusted $R^2 = 0.320$, $F(4, 38) = 5.91$, $p < .001$). The model explained 38.4% of the variance in clinical throughput performance. Among the four predictors, only system downtime and error frequency demonstrated a statistically significant predictive relationship ($\beta = 0.407$, $p = 0.005$). System usage time, image retrieval speed, and reporting turnaround time did not demonstrate significant individual predictive effects. The findings identify system downtime and error frequency as the only statistically significant PACS-related predictor within the regression model, highlighting the operational relevance of system reliability. Dhamija et al. (2022) emphasized that unplanned PACS downtime can disrupt clinical operations and delay patient care. Similarly, Jabin et al. (2024) documented how software configuration problems associated with system upgrades disrupted medical imaging workflows. These studies reinforce the importance of reliable infrastructure, preventive maintenance, and responsive technical support in maintaining radiology operations.

3.3 Proposed Radiology Workflow Optimization Strategies

3.3.1 System Reliability and Image Retrieval Optimization

The findings identified system downtime and error frequency as the strongest significant PACS-related predictor of clinical throughput performance. Respondents also reported difficulties involving image loading and retrieval of archived imaging studies. Accordingly, the proposed strategies include preventive maintenance, server redundancy, backup systems, improved network connectivity, responsive technical support, database optimization, and upgraded storage infrastructure. These strategies prioritize uninterrupted PACS operations and

improved accessibility of diagnostic images. Dhamija et al. (2022) demonstrated the importance of contingency planning and alternative image-viewing systems during PACS downtime. Jabin et al. (2024) further highlighted the need for preventive and corrective strategies addressing technical problems in medical imaging systems. Additionally, Becker et al. (2024) examined automated microservices as a means of streamlining radiology workflows. These studies provide support for strengthening infrastructure reliability and improving the technical processes that sustain imaging operations.

3.3.2 System Integration, Accessibility, and Staff Competency

The study identified fragmented hospital information systems, limited PACS accessibility across clinical areas, and inadequate formal training among some personnel as concerns requiring operational improvement. Proposed strategies include integrating PACS with Radiology Information Systems (RIS), Hospital Information Systems (HIS), and Electronic Medical Records (EMR); expanding PACS access to emergency departments, hospital wards, and physician workstations; and implementing structured training and continuous competency development programs. Improved interoperability may minimize repetitive encoding, facilitate clinical information exchange, and strengthen coordination among healthcare professionals. Tejani et al. (2024) emphasized the importance of standardized interoperability and integration in radiology workflows. Meanwhile, Gullotti et al. (2025) demonstrated that structured PACS training improved radiology residents' technical proficiency and confidence. In the Philippine setting, Canguit and Sison (2025) identified relevant diagnostic efficiency benefits and adaptation challenges among radiologic technologists using PACS. These findings reinforce the importance of combining technological integration with continuous personnel development to support efficient digital radiology operations.

3.3.3 Patient Flow and Workflow Management

Patient waiting time obtained the lowest mean among the scored clinical throughput indicators ($M = 3.56$, $SD = 0.69$), indicating an opportunity for operational improvement despite the generally high throughput performance. The proposed interventions include digital scheduling systems, queue management, patient triaging, appropriate staff allocation, and workload balancing. These measures are intended to reduce workflow bottlenecks, improve coordination of imaging procedures, and support consistent patient movement through diagnostic services. Law et al. (2024) reported significant reductions in radiology reporting turnaround times and workflow interruptions following the implementation of an integrated automatic examination assignment system. Similarly, Bharadwaj et al. (2024) highlighted the value of selecting workflow applications according to operational needs and demonstrated efficiency benefits. These studies support the proposed integration of digital scheduling, coordinated workflow management, and reliable imaging infrastructure to improve radiology service delivery.

4. Conclusion & Recommendations

The study concludes that Picture Archiving and Communication System (PACS) utilization efficiency is significantly and positively associated with clinical throughput performance in selected tertiary diagnostic imaging departments. PACS utilization efficiency was moderately high ($M = 3.48$), while clinical throughput performance was high ($M = 3.80$), indicating generally efficient radiology operations. A significant positive relationship was established between the variables ($r = 0.581$, $p < .001$), with PACS utilization indicators explaining 38.4% of the variance in clinical throughput performance. Among the four predictors, only system downtime and error frequency demonstrated a significant predictive relationship ($\beta = 0.407$, $p = 0.005$), emphasizing the importance of system reliability in maintaining workflow efficiency. These findings highlight the role of PACS in supporting diagnostic productivity, patient flow, and efficient healthcare service delivery.

Healthcare institutions should prioritize PACS reliability through preventive maintenance, server optimization, backup systems, improved network infrastructure, and responsive technical support to minimize operational disruptions. Upgrading storage systems, optimizing image retrieval, and integrating PACS with Radiology Information Systems (RIS), Hospital Information Systems (HIS), and Electronic Medical Records (EMR) are recommended to enhance information accessibility and workflow coordination. Expanding PACS access across clinical departments, strengthening staff training, implementing digital scheduling and queue management, and monitoring key performance indicators are likewise encouraged to improve patient throughput and service efficiency. Future research should examine additional organizational, human, and patient-related factors influencing clinical throughput through longitudinal and multicenter investigations.

The study was limited to 43 radiology personnel from selected tertiary hospitals in Batangas, Philippines, using purposive sampling and a non-experimental correlational research design. Consequently, the findings are specific to the participating institutions, and the observed relationships do not establish causality. The limited sample size and geographical coverage should also be considered when interpreting the findings and their applicability to other diagnostic imaging departments.

5. Compliance with ethical standards

The authors affirm that no conflicts of interest exist in relation to this study. The research was conducted in accordance with established ethical principles for studies involving human participants. Prior permission was obtained from the administrators and department heads of the participating tertiary hospitals in Batangas, Philippines. All radiologic technologists, radiologists, and diagnostic imaging personnel were informed of the study's objectives and procedures before providing informed consent. Participation was voluntary, and respondents were assured of their right to withdraw at any stage without penalty. Confidentiality and anonymity were maintained throughout data collection and analysis, and the information obtained was used exclusively for academic and research purposes. As the study involved a non-invasive, questionnaire-based assessment of Picture Archiving and Communication System (PACS) utilization efficiency and clinical throughput performance, no experimental interventions or alterations to routine clinical operations were undertaken. Ethical safeguards were observed to protect participants' privacy, professional interests, and the confidentiality of institutional information.

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