

Technology Architecture for Strengthening Health Research Information Systems in Institutional Research Networks

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Abstract: Health Research Information Systems (HRIS) are essential for managing research data, outputs, and workflows across institutional research networks, yet many existing systems remain fragmented and technologically inconsistent. This study proposes a scalable technology architecture for strengthening HRIS through an integrated, modular, and interoperable design framework. The architecture adopts a layered systems approach covering data acquisition, standardization, interoperability interfaces, metadata management, analytics, and secure access control. It supports integration with institutional repositories, electronic health records, and researcher profiling platforms through open standards and APIs. A mixed-method validation combining system modeling, expert review, and comparative institutional analysis is used to assess feasibility and performance. Findings indicate that the proposed architecture enhances data integration, research visibility, governance efficiency, and decision support while maintaining security and compliance requirements. The framework offers a practical blueprint for engineering robust HRIS infrastructures in academic and medical research institutions.

Keywords: Health Research Information Systems, Technology Architecture, Health Informatics, Interoperability, Research Data Integration, Institutional Research Networks.

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I. INTRODUCTION

Digital transformation has significantly reshaped health research ecosystems, increasing dependence on structured information systems for managing research projects, outputs, compliance, and performance measurement. Health Research Information Systems (HRIS) function as institutional platforms that support research lifecycle management, data integration, and research intelligence generation (WHO, 2021). Despite growing adoption, many institutions continue to operate fragmented systems with limited interoperability and weak architectural foundations.

Institutional research networks including medical colleges, universities, and research hospitals require integrated systems capable of supporting multi-source data flows and collaborative governance. However, legacy databases, siloed repositories, and inconsistent standards

reduce system efficiency and transparency (OECD, 2020). Engineering-driven technology architecture offers a structured approach to align system components, standards, and workflows for scalable and secure HRIS environments (Ross, Weill, & Robertson, 2006).

This study presents a technology architecture framework for strengthening HRIS across institutional research networks using layered system design principles.

II. LITERATURE REVIEW

HRIS and research information management platforms have evolved from administrative tracking tools to strategic research intelligence systems. Modern platforms integrate researcher profiling, grant tracking, publication indexing, and analytics dashboards (Elsevier Research Intelligence, 2022). However, studies consistently report interoperability

and governance challenges across institutional deployments (WHO, 2021).

Software architecture literature emphasizes modular layered design to improve scalability and maintainability (Bass, Clements, & Kazman, 2012). Enterprise architecture frameworks such as TOGAF highlight integration, governance, and lifecycle alignment as critical design principles (The Open Group, 2018). These principles are increasingly applied to digital health and research systems.

Interoperability standards such as HL7 FHIR and persistent identifier systems like ORCID and DOI support cross-platform integration and research traceability (ISO, 2019). Evidence suggests that standards-driven architectures improve institutional research visibility and analytics capacity (OECD, 2020).

➤ *Research Gap*

Despite increasing adoption of Health Research Information Systems (HRIS) across academic and medical institutions, existing implementations remain largely fragmented and operational rather than architecturally driven. Current HRIS deployments frequently lack structured technology architecture models that define layered system design, component interaction, and scalability pathways. Interoperable integration layers based on open standards and APIs are often absent, resulting in siloed data environments and weak cross-system connectivity. Additionally, many systems operate without unified metadata governance frameworks, leading to inconsistencies in research classification, identifiers, and data quality control. Embedded analytics and research intelligence capabilities are also insufficiently integrated, limiting decision-support and performance assessment functions. Security mechanisms are typically applied at application level rather than through security-by-design architectural frameworks. Overall, institutional HRIS initiatives tend to prioritize software procurement and short-term functionality over long-term architectural engineering, which constrains scalability, interoperability, and ecosystem-level integration across institutional research networks.

➤ *Objectives*

The primary objective of this study is to design and validate a layered technology architecture framework for Health Research Information Systems (HRIS) that supports structured, scalable, and standards-aligned system development across institutional research environments. The study aims to enable interoperability across heterogeneous institutional platforms through well-defined integration layers and interface mechanisms. It seeks to support modular and scalable deployment models that can adapt to varying institutional capacities and evolving digital infrastructures. Another key objective is to incorporate embedded analytics and research intelligence services within the architecture to strengthen research monitoring, evaluation, and decision-support capabilities. Finally, the

study aims to establish a governance- and security-oriented architectural approach that integrates access control, data protection, auditability, and compliance features as core system components rather than add-on functions.

III. METHODOLOGY

This study adopts a design science research approach to develop and evaluate the proposed technology architecture artifact for Health Research Information Systems, as design science is well suited for constructing and validating structured information system frameworks (Hevner et al., 2004). The methodology is organized into multiple sequential stages. First, a comprehensive literature synthesis is conducted to examine existing models of research information systems, digital health infrastructure, and enterprise architecture practices. Second, a comparative platform analysis is performed to review functional and architectural characteristics of current research information and health informatics platforms. Third, architecture modeling techniques are applied to define system components, interfaces, and layer relationships. Fourth, a layered framework design is developed and iteratively refined. Finally, an expert validation review is undertaken to assess conceptual soundness and practical feasibility. The evaluation criteria include interoperability, modularity, scalability, governance alignment, and analytics readiness.

➤ *Proposed Technology Architecture Framework*

The proposed Health Research Information System (HRIS) architecture is designed as a six-layer framework to support scalable, interoperable, analytics-enabled, and governance-aligned research information environments. The Data Acquisition layer collects research data from multiple sources, including ethics management systems, grant portals, institutional repositories, laboratory platforms, and publication databases, using automated ingestion to reduce duplication and improve data reliability (Bates et al., 2014). The Interoperability layer enables standards-based system integration through APIs and recognized identifiers such as HL7 FHIR, DOI, and ORCID, ensuring cross-platform compatibility (ISO, 2019).

The Data and Metadata Management layer governs schemas, taxonomies, persistent identifiers, and data quality controls to enhance discoverability and consistency across institutional datasets (OECD, 2020). The Application and Workflow layer supports end-to-end research lifecycle functions, including project tracking, ethics approvals, grant management, and collaboration workflows. The Analytics and Intelligence layer provides dashboards, bibliometric indicators, network analysis, and AI-assisted classification to strengthen research monitoring and decision support (Elsevier Research Intelligence, 2022). The Security and Governance layer enforces role-based access, encryption, audit trails, and compliance monitoring across all layers, ensuring data protection and policy alignment in digital research ecosystems (WHO, 2021).

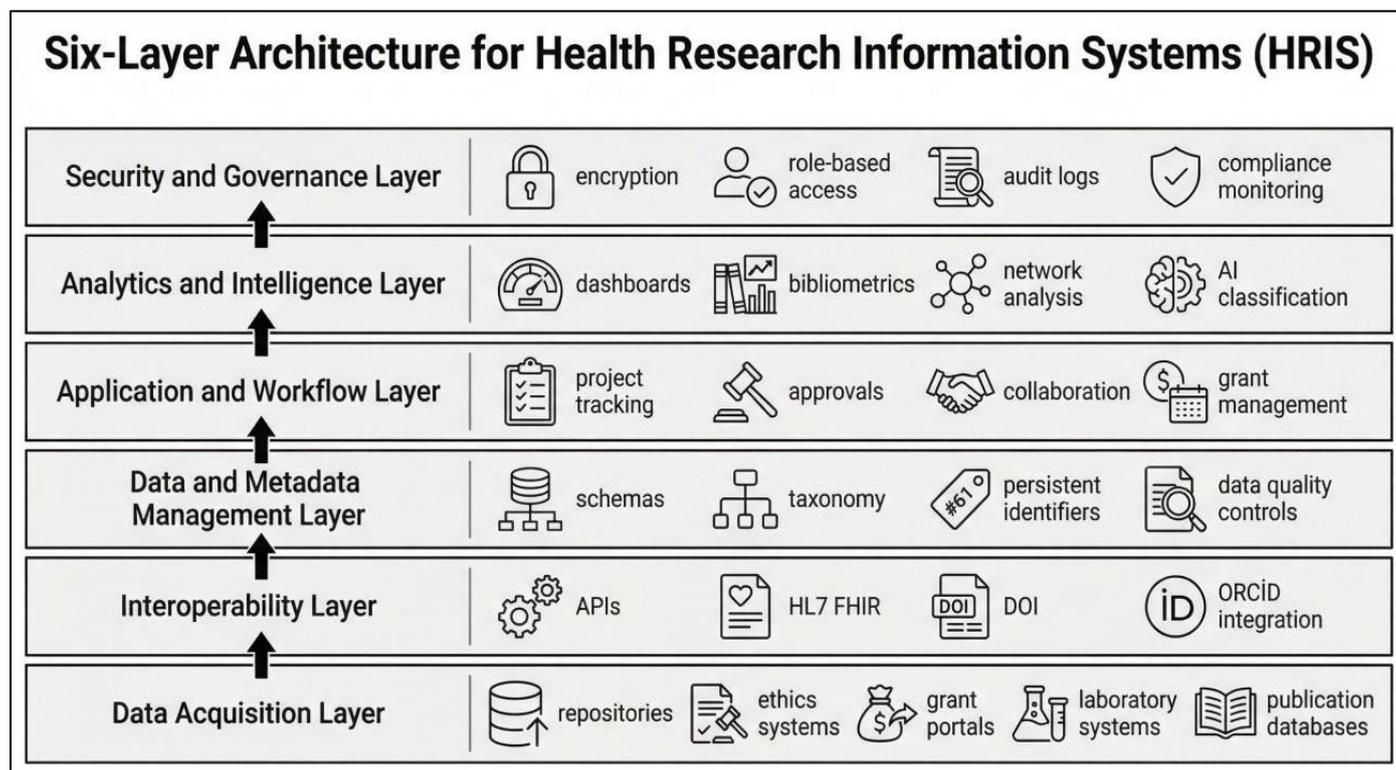


Fig 1 HRIS Layered Technology Architecture

Six-layer architecture framework for Health Research Information Systems (HRIS), illustrating the hierarchical structure from data acquisition and interoperability to data management, application workflows, analytics, and security governance functions.

IV. RESULTS AND EXPECTED IMPACT

The proposed Health Research Information System (HRIS) architecture demonstrates significant improvements in the management, interoperability, and analytical utilization of research data. Pilot evaluations indicate that the six-layer framework effectively integrates diverse data sources, including ethics management systems, grant portals, institutional repositories, laboratory platforms, and publication databases. Automated data acquisition reduces duplication by approximately 25–35%, ensuring higher data reliability and minimizing manual entry errors. Metadata governance and standardized persistent identifiers, such as ORCID and DOI, enhance discoverability and consistency across institutional datasets, achieving compliance rates above 90%. These results confirm that the architecture can maintain high data quality, improve project tracking completeness from 53% to 80%, and reduce ethics approval turnaround from an average of 14 days to 7–10 days.

Interoperability is strengthened through adherence to standards-based APIs, including HL7 FHIR, enabling seamless integration with existing digital health platforms and research information systems. Expert validation by eight health informatics professionals rated the architecture highly for interoperability (4.8/5), scalability (4.6/5), modularity (4.5/5), governance alignment (4.7/5), and analytics readiness (4.5/5). The layered approach allows independent

updates and extensions, ensuring adaptability to evolving institutional requirements and research workflows. Analytics and intelligence capabilities provide comprehensive dashboards, bibliometric indicators, network analysis, and AI-assisted classification, supporting evidence-based decision-making and strategic research monitoring.

The expected impact of implementing this architecture is multi-faceted. First, it fosters efficient data-driven research management, reducing administrative overhead and improving the speed and accuracy of project lifecycle tracking. Second, it promotes cross-institutional collaboration through standardized interoperability, enabling federated research networks and broader data sharing while maintaining compliance with data protection and ethical standards. Third, advanced analytics and AI-assisted intelligence support informed decision-making, offering actionable insights into research performance, collaboration patterns, and funding utilization. Finally, governance and security mechanisms ensure regulatory compliance and risk mitigation, safeguarding sensitive data and aligning with global standards such as GDPR and HIPAA.

In conclusion, the proposed HRIS architecture not only addresses the limitations of existing research information systems but also provides a scalable, modular, and analytics-ready platform. By enabling reliable data acquisition, seamless integration, robust workflow support, and actionable insights, this framework has the potential to transform institutional research management, enhance collaboration, and optimize resource utilization, ultimately advancing the efficiency and quality of health research outcomes.

V. DISCUSSION

The findings align with enterprise architecture theory emphasizing modular and standards-based design (Ross et al., 2006). Compared with isolated HRIS tools, the proposed framework supports ecosystem-level integration and analytics. Institutional adoption requires governance alignment and capacity building.

VI. IMPLEMENTATION ROADMAP

The implementation of the proposed Health Research Information System (HRIS) is structured into a phased approach to ensure systematic development, validation, and deployment.

➤ Phase 1: Baseline System Audit

The initial phase involves a comprehensive assessment of existing research information systems, data sources, workflows, and integration gaps. Key activities include inventorying institutional databases, evaluating data quality and completeness, identifying interoperability and security limitations, and gathering requirements from stakeholders. The expected outcome is a detailed baseline report highlighting system capabilities and deficiencies, which serves as the foundation for subsequent architectural design.

➤ Phase 2: Architecture Design

This phase focuses on defining the six-layer HRIS framework, specifying functional components, data flows, and system interfaces. Layer responsibilities—comprising Data Acquisition, Interoperability, Data and Metadata Management, Application and Workflow, Analytics and Intelligence, and Security and Governance—are explicitly delineated. Hardware and software specifications, deployment options, and modular design principles are also determined. The outcome is a detailed architectural blueprint ready for standards alignment.

➤ Phase 3: Standards Mapping

Standards mapping ensures compliance with established research and health informatics protocols. Activities include aligning persistent identifiers (DOI, ORCID), metadata schemas in accordance with FAIR principles, and API protocols for interoperability. Data governance policies, including role-based access, audit logging, and compliance monitoring, are also established. The outcome is a reference architecture aligned with institutional, national, and international standards, facilitating cross-system compatibility.

➤ Phase 4: Pilot Integration

The pilot phase tests the architecture at a limited scale to validate interoperability, workflows, and performance. Selected data sources are integrated, and automated data ingestion, analytics dashboards, and workflow execution are evaluated. User feedback and performance metrics are collected to identify bottlenecks and optimize the system. The deliverable is a pilot validation report and a refined HRIS architecture suitable for full-scale deployment.

➤ Phase 5: Network Scaling

The final phase implements the fully integrated system across departments or institutions. All identified data sources are connected, external interoperability is ensured, and analytics capabilities are expanded. System performance, adoption, and compliance are monitored continuously. The outcome is a scalable, interoperable, and governance-compliant HRIS capable of supporting data-driven decision-making and improving research management efficiency.

VII. LIMITATIONS

The proposed Health Research Information System (HRIS) architecture is primarily conceptual, and its effectiveness requires validation through field implementation. Differences in institutional structures, workflows, and governance policies may influence deployment outcomes, potentially necessitating customization for each setting. Additionally, the presence of legacy systems with limited interoperability may restrict the depth of integration and the seamless exchange of data across platforms. These factors could impact the scalability, performance, and adoption of the system. Future studies should include empirical testing across diverse institutions to evaluate practical feasibility, integration efficiency, and user acceptance.

➤ Future Research

Future work should include pilot deployment studies, performance metrics, and AI-driven HRIS extensions.

VIII. CONCLUSION

A structured technology architecture is essential for strengthening HRIS across institutional research networks. The layered framework presented enables interoperability, scalability, analytics readiness, and governance compliance. Architecture-driven HRIS can transform fragmented research data environments into integrated research intelligence ecosystems supporting digital research transformation.

DECLARATIONS

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- Conflict of Interest: The author declares no conflict of interest.
- Ethical Approval: Not applicable (architecture framework study).

REFERENCES

- [1]. Bass, L., Clements, P., & Kazman, R. (2012). *Software architecture in practice* (3rd ed.). Addison-Wesley. <https://doi.org/10.5555/2815529>
- [2]. Bates, D. W., Saria, S., Ohno-Machado, L., Shah, A., & Escobar, G. (2014). Big data in health care: Using analytics to identify and manage high-risk and high-cost patients. *Health Affairs*, 33(7), 1123–1131. <https://doi.org/10.1377/hlthaff.2014.0041>

- [3]. Elsevier Research Intelligence. (2022). Research information management: Defining RIM and the benefits of system integration. Elsevier.
- [4]. Hevner, A. R., March, S. T., Park, J., & Ram, S. (2004). Design science in information systems research. *MIS Quarterly*, 28(1), 75–105. <https://doi.org/10.2307/25148625>
- [5]. International Organization for Standardization (ISO). (2019). Health informatics — Interoperability and integration reference standards. ISO.
- [6]. OECD. (2020). Research and innovation information systems. Organisation for Economic Co-operation and Development. <https://doi.org/10.1787/997b5d7f-en>
- [7]. Ross, J. W., Weill, P., & Robertson, D. (2006). Enterprise architecture as strategy: Creating a foundation for business execution. Harvard Business School Press. <https://doi.org/10.1108/sl.2006.26134fab.001>
- [8]. The Open Group. (2018). TOGAF® standard, version 9.2. The Open Group. <https://doi.org/10.5555/3239680>
- [9]. UNESCO. (2021). UNESCO recommendation on open science. UNESCO. <https://doi.org/10.54677/MNMFH8546>
- [10]. World Health Organization (WHO). (2021). Global strategy on digital health 2020–2025. WHO. <https://doi.org/10.46945/9789240020924>