Developing a FAIR-Compliant RDM Framework: Insights from TU Wien and ITB

Wikan Danar Sunindyo, Hari Purnama, Saiful Akbar, Dicky Prima Satya

Knowledge and Software Engineering Research Group
Institut Teknologi Bandung
Jl. Ganesa 10 Bandung Indonesia 40132

{wikan, purnama, Saiful, dicky}@informatika.org

Martin Weise[1], Florina Piroi[1,2], Andreas Rauber[1]

[1]*Faculty of Informatics,* [2]*CRDM*
Technische Universitat Wien
Favoritenstrasse 9-11, Wien, Austria 1040

{martin.weise, florina.piroi, andreas.rauber} @tuwien.ac.at

***Abstract* - The growing demand for open science and data-intensive research highlights the urgent need for robust Research Data Management (RDM) systems in universities. While European institutions such as TU Wien have implemented mature FAIR-compliant infrastructures, Indonesian universities still face challenges of fragmented repositories, limited interoperability, and the absence of institutional policies. This paper presents the development of a FAIR-compliant RDM framework tailored for Institut Teknologi Bandung (ITB), derived from lessons learned at TU Wien. The framework integrates five pillars—Policy & Governance, Infrastructure, Processes & Services, Trust & Quality, and Capacity Building—supported by an implementation roadmap. A prototype system was developed using open-source components (InvenioRDM, DBRepo, JupyterHub) to enable research and business intelligence dashboards. Comparative analysis shows that the proposed framework bridges global best practices with local needs, providing both theoretical contributions to institutional data governance and practical tools for evidence-based decision-making. The outcomes aim to strengthen institutional research transparency, support Indonesia's innovation agenda, and offer a replicable model for other universities.**

Index Terms* - *FAIR principles, research data management, open science, institutional research mapping.

I. Introduction

The rapid expansion of data-intensive research has positioned Research Data Management (RDM) as a critical enabler of scientific excellence, institutional competitiveness, and evidence-based policymaking. Properly managed research data not only accelerates discovery but also supports reproducibility and enhances interdisciplinary collaboration across domains. In Europe, initiatives such as the European Open Science Cloud (EOSC)[1] and FAIR Data Austria[2] or German National Research Data Infrastructures[3] have demonstrated how the FAIR principles (Findable, Accessible, Interoperable, and Reusable) create national and institutional ecosystems. These initiatives highlight the transformative role of FAIR-compliant infrastructures in fostering open science and enabling large-scale research integration.

In Indonesia, the urgency of strengthening RDM is explicitly recognized in the *Asta Cita* national agenda [1] and Institut Teknologi Bandung's (ITB) Research Roadmap 2025–2050[2], both of which emphasize innovation, open science, and global competitiveness. Nevertheless, universities across the country continue to face significant challenges, including fragmented repositories, limited interoperability, and the absence of institutional policies and guidelines. These barriers not only hinder institutional research mapping but also reduce the effectiveness of national innovation strategies and limit opportunities for international collaboration.

This paper addresses these gaps by proposing the development of a FAIR-compliant RDM framework tailored for ITB, informed by lessons learned from Technische Universität Wien (TU Wien). Beyond conceptual design, the contributions of this paper are threefold:

1. The formulation of a five-pillar framework encompassing Policy & Governance, Infrastructure, Processes & Services, Trust & Quality, and Capacity Building.
2. The design of a staged roadmap for institutional implementation, ensuring gradual and sustainable FAIR adoption.
3. The development of an initial prototype system integrating open-source tools (InvenioRDM, DBRepo, and JupyterHub) to enable automated research and business intelligence dashboards.

Accordingly, this research is guided by the following central question:

How can a FAIR-compliant RDM framework be developed and operationalized at ITB to enhance institutional research mapping while providing a replicable model for other Indonesian universities?

The remainder of this paper is structured as follows. Section II reviews related works on FAIR principles and institutional RDM practices. Section III outlines the research methodology, including comparative analysis and framework co-design. Section IV presents the proposed FAIR-compliant RDM framework, implementation roadmap, and prototype system for ITB. Section V discusses theoretical and practical

[1] https://research-and-innovation.ec.europa.eu/strategy/strategy-research-and-innovation/our-digital-future/open-science/european-open-science-cloud-eosc_en
[2] https://forschungsdaten.at/en/fair-data-austria/
[3] https://www.nfdi.de/?lang=en

implications as well as challenges. Finally, Section VI concludes the paper and outlines directions for scaling the framework towards national and regional open science initiatives.

II. Related Works

A. FAIR Principles and Open Science

The FAIR principles—Findable, Accessible, Interoperable, and Reusable—introduced by Wilkinson et al. [3], have become a global benchmark for describing and managing research data. FAIR emphasizes both human readability and machine actionability, enabling automated discovery, integration, and reuse of data across domains. Recent studies expanded these principles to institutional and national levels, stressing the importance of persistent identifiers (e.g., DOI [4], ORCID [5]), standardized metadata schemas, and data stewardship policies [4]. In parallel, open science movements such as the European Open Science Cloud (EOSC) illustrate how FAIR can be operationalized through shared infrastructures and governance models [5].

B. RDM Practices in European Universities

European universities have developed mature ecosystems to support FAIR-compliant RDM. TU Wien exemplifies this maturity through a multi-repository architecture integrating DSpace [6], Invenio [7], GitLab [8], and DBRepo [9] [6], combined with machine-actionable Data Management Plans (maDMPs) [10] [7] and sensitive data handling frameworks such as OSSDIP [8]. Other institutions, including the UK's Jisc RDM programs[11], the Netherlands' DANS repository[12], and Germany's National Research Data Infrastructure (NFDI), demonstrate systemic alignment between national policies and institutional infrastructures. These examples highlight how coordinated strategies across policy, infrastructure, and training can accelerate FAIR adoption at scale [9].

C. RDM in Asian and Developing Contexts

In contrast, RDM adoption in Asia and other developing regions remains fragmented. Studies reveal persistent barriers, including the absence of institutional RDM policies, limited technical infrastructure, and low awareness or literacy among researchers [10]. While countries such as China [11], India [12], and Malaysia [13] have initiated open science policies and national repositories, these efforts often lack interoperability and FAIR compliance. Capacity-building programs, when available, are limited in scope or unsystematic, making it challenging to achieve sustainable cultural change toward open science [14].

D. RDM in Indonesia

Indonesia has recently introduced the Indonesia Open Science Policy [10] as part of its national research and innovation agenda. However, operationalization at the institutional level remains limited. Existing repositories in Indonesian universities are primarily restricted to thesis collections and publication archives, without integrated support for metadata standards, persistent identifiers, or sensitive data handling. At Institut Teknologi Bandung (ITB), research data remains scattered across faculties and research groups, with no central governance or FAIR-compliant workflows. This fragmentation reduces data visibility, weakens institutional competitiveness, and hinders alignment with national innovation goals.

E. Research Gap

From the literature, two apparent gaps emerge. First, while European universities demonstrate how FAIR principles can be operationalized through integrated infrastructures, policies, and training, these practices have not been systematically adapted to the context of developing universities. Second, in Indonesia, despite the existence of national Open Science policies, no institutional-scale, FAIR-compliant RDM framework has yet been proposed or implemented. To the best of our knowledge, this paper is the first to address these gaps by proposing a FAIR-compliant RDM framework tailored for ITB, informed by TU Wien's best practices, and supported by an initial prototype system. The framework contributes theoretically by extending institutional RDM models into developing contexts, and practically by offering a replicable model for other Indonesian universities.

III. Methodology

This research follows a sequential four-phase methodology, ensuring logical traceability from problem identification to prototype validation.

1. **Benchmarking**: Comparative analysis of TU Wien and ITB to identify policy and technical gaps.
2. **Co-Design**: Joint formulation of the five-pillar FAIR RDM framework.
3. **Prototype Development**: Technical realization using InvenioRDM, DBRepo, and JupyterHub within ITB's infrastructure.
4. **Evaluation**: Preliminary validation through stakeholder feedback and readiness assessment based on the RDA FAIR Maturity Model.

This structured approach ensures transparent linkage between institutional context, design decisions, and validation outcomes.

A. Research Design

The research follows a Design Science Research (DSR) [15] cycle, combining problem identification, artifact design, and evaluation. The comparative case study approach provides

[4] Digital object identifier
[5] Open Researcher and Contributor ID
[6] https://dspace.org/
[7] https://inveniosoftware.org/products/rdm/
[8] https://gitlab.com/gitlab-org/gitlab
[9] https://www.ifs.tuwien.ac.at/infrastructures/dbrepo/1.10/
[10] http://ifs.tuwien.ac.at/~miksa/papers/2018-iPres-maDMPs.pdf
[11] https://www.jisc.ac.uk/research-management
[12] https://dans.knaw.nl/en/

empirical grounding, while the design-oriented perspective ensures that the proposed framework is actionable and replicable.

B. Data Collection and Benchmarking

To ensure that the framework design was grounded in both empirical evidence and institutional realities, data collection was carried out using multiple complementary sources. This triangulated approach allowed us to capture policy documents, stakeholder perspectives, and best practices from leading institutions. Specifically, the data collection process included the following:

(1) Document Analysis: Institutional policies, RDM guidelines, and repository documentation from TU Wien and ITB.

(2) Workshops and Focus Groups: Engaging stakeholders such as researchers, librarians, IT staff, and policymakers at ITB to identify needs and barriers.

(3) Benchmarking Visits: Discussions with TU Wien's Research Data Management Unit to capture best practices and lessons learned.

C. Framework Co-Design

Based on the benchmarking activities described above, a five-pillar framework was co-designed to address the identified gaps and guide institutional adoption of FAIR principles. The framework provides a holistic structure that integrates governance, technology, processes, quality assurance, and human capacity. It consists of the following pillars:

(1) **Policy & Governance** establishes institutional mandates and ensures regulatory alignment.
(2) **Infrastructure** provides the technological foundation that enables implementation of policies.
(3) **Processes & Services** operationalize FAIR workflows through standardized data management procedures.
(4) **Trust & Quality** ensures reliability via metadata standards, identifiers, and provenance control.
(5) **Capacity Building** sustains the ecosystem by improving literacy, training, and community participation.

These pillars form a cyclic dependency: Policy drives Infrastructure development, Infrastructure enables Processes, Processes foster Trust, and Trust can only be sustained through continuous Capacity Building, which in turn reinforces Policy evolution.

D. Prototype Development

Before delving into the development of the technical prototype, it is essential to emphasize the role of institutional policies as the enabling framework for sustainable Research Data Management (RDM). At TU Wien, the adoption of open science and FAIR-compliant policies has proven critical to aligning technical infrastructures with cultural and organizational practices. Building on this experience, a preliminary set of policies has been drafted for Institut Teknologi Bandung (ITB), with slight adaptations to reflect the local institutional context, governance structures, and national regulations. These policies aim to provide clear guidelines on data stewardship, repository usage, metadata standards, and responsibilities of stakeholders. The process of internal consultation and endorsement has been initiated to ensure acceptance across faculties and research units, with the goal of having the policy formally adopted at ITB.

Supporting the above-mentioned policy, a prototype system is being developed to operationalize these policies. The guiding principle is institutional autonomy: rather than relying on external online platforms, ITB aims to establish its own services within a university-managed, on-premises private cloud environment. This approach guarantees data sovereignty, compliance with local regulations, and resilience against external dependencies.

The prototype integrates three open-source components within ITB's on-premise private cloud environment:
(1) **InvenioRDM** acts as the central metadata and object repository. It exposes RESTful APIs (JSON-based) for metadata ingestion and retrieval, supporting the DataCite schema for DOI assignment.
(2) **DBRepo** serves as a structured data backend for tabular and relational datasets, connected to InvenioRDM through a custom synchronization service that maps dataset identifiers and metadata keys.
(3) **JupyterHub** provides computational reproducibility and notebook execution, allowing researchers to document, share, and re- execute code and workflows within the ITB infrastructure.

Workflow Example. When a researcher uploads a new dataset via the RDM portal, the system automatically:
1. Generates metadata fields (title, authors, keywords, license) according to the FAIR template;
2. Requests a DOI from the institutional DataCite account;
3. Stores the dataset in DBRepo and links it to InvenioRDM via API;
4. Updates the Business Intelligence dashboard, which visualizes the dataset's status and usage metrics for institutional reporting.

This architecture ensures metadata consistency across platforms, minimizes manual curation, and demonstrates a feasible pathway for institutional-level FAIR implementation. Initial API integration tests with ITB's existing publication systems indicate successful metadata synchronization and highlight future potential for full interoperability.

The overarching goal of this prototype is to create a testbed environment where policies and technical solutions can be jointly evaluated and aligned with researchers' actual needs. Once validated, the system will evolve into a centrally managed institutional service, providing sustainable, sovereign, and FAIR-compliant RDM for the entire ITB research ecosystem.

E. Roadmap Formulation

An implementation roadmap was designed using staged planning (2025–2028+), covering four phases: foundation, infrastructure, expansion, and sustainability.

F. Evaluation Strategy

The framework and prototype will be evaluated through mixed methods:

(1) Surveys: Measuring researcher perceptions of usability, FAIR literacy, trustworthiness, and readiness for adoption.
(2) System Logs: Monitoring data ingestion, metadata compliance, and user activity.
(3) Expert Interviews: Gathering qualitative feedback from ITB and TU Wien stakeholders to refine the framework.

IV. Results

A. Comparative Analysis: TU Wien vs ITB

The benchmarking revealed significant differences between TU Wien's mature but still evolving RDM ecosystem and ITB's current practices:

(1) Policy & Governance – TU Wien has an institutional RDM policy (2018[13], revised 2023[14]) supported by a dedicated unit, while ITB lacks a formal policy or governance structure.
(2) Infrastructure – TU Wien maintains an integrated multi-repository ecosystem (DSpace, InvenioRDM, GitLab, DBRepo). ITB only operates a publication repository with limited interoperability.
(3) Processes & Services – TU Wien applies machine-actionable Data Management Plans (maDMPs) and standardized workflows; ITB has no such mechanisms.
(4) Trust & Quality – TU Wien ensures DOI assignment, FAIR metadata compliance, and provenance tracking. ITB lacks persistent identifiers and quality assurance protocols.
(5) Capacity Building – TU Wien conducts regular training and awareness programs; ITB provides limited ad-hoc training.

This comparative study underlines the urgent need for a structured, FAIR-compliant framework at ITB, as shown in Table 1.

B. Proposed FAIR-Compliant RDM Framework

The proposed framework is structured around five interconnected pillars:

(1) Policy & Governance – Establishing an institutional RDM policy, a dedicated RDM Unit, and alignment with national initiatives (e.g., BRIN's Open Science Policy).
(2) Infrastructure – Developing an integrated ecosystem combining repositories, computational platforms, and secure environments for sensitive data.
(3) Processes & Services – Introducing maDMPs, single sign-on (SSO) integration, and researcher support services for data submission and curation.
(4) Trust & Quality – Implementing persistent identifiers (DOI, ORCID), metadata standards, and reproducibility protocols to ensure transparency.
(5) Capacity Building – Training, outreach, and collaboration to build FAIR literacy among researchers and staff.

Table 1 Comparative Analysis of RDM Practices at TU Wien and ITB

Aspect	TU Wien	ITB
Policy & Governance	RDM Policy (2018, revised 2023), dedicated RDM Unit	No formal RDM policy, no dedicated unit
Infrastructure	Multi-repository ecosystem (DSpace, InvenioRDM, GitLab, DBRepo)	Single publication repository, limited interoperability
Processes & Services	Machine-actionable Data Management Plans (maDMPs), standardized workflows	No maDMPs or standardized workflows
Trust & Quality	DOI assignment, FAIR metadata compliance, emerging provenance tracking	No persistent identifiers, limited metadata standards
Capacity Building	Regular training, outreach, and researcher awareness programs, curriculum integration	Limited and ad-hoc training programs

C. Implementation Roadmap for ITB

A staged roadmap has been formulated to ensure gradual but sustainable adoption:

(1) Stage 1 (2025–2026): Foundations
   a. Establish ITB RDM Policy and RDM Unit.
   b. Initial FAIR awareness training for researchers.
(2) Stage 2 (2026–2027): Infrastructure & Services
   a. Deploy institutional repository integrated with maDMPs and SSO.
   b. Launch support services for metadata curation and DOI assignment.
(3) Stage 3 (2027–2028): Expansion
   a. Integrate JupyterHub for computational reproducibility.
   b. Enable FAIR datasets with provenance tracking and interoperability.
(4) Stage 4 (2028+): Trust & Sustainability

[13] https://www.tuwien.at/en/research/rti-support/research-data/info-and-guidelines/policy#:~:text=It%20is%20important%20to%20preserve,whenever%20possible%20reusable%20and%20replicable.

[14] https://www.tuwien.at/index.php?eID=dms&s=4&path=Directives%20and%20Regulations%20of%20the%20Rectorate/Policy%20for%20Research%20Data%20Management.pdf

a. Implement an OSSDIP-like trusted research environment (TRE) system for secure sensitive data handling.
b. Achieve CoreTrustSeal certification for long-term trust and credibility.

D. Prototype System

An initial prototype system is being developed to demonstrate feasibility of:

(1) Automated Data Harvesting – Collecting research outputs from ITB's publication system and departmental repositories.
(2) Research Data Curation – Organizing data at individual and group levels to support ITB's Research Roadmap 2025–2050.
(3) Business Intelligence (BI) Dashboards – Providing analytics to support ITB's Technology Outlook and evidence-based decision-making.

As a potential case study, the prototype is intended to be connected with ITB's institutional publication repository. In this planned scenario, metadata from recent publications could be harvested via API and ingested into the InvenioRDM platform. The dataset would then be organized by faculty and research group to demonstrate the capability of research roadmap curation. Furthermore, JupyterHub could be used to generate analytical visualizations (e.g., co-authorship networks or topic trends), providing a proof-of-concept for how the system might support both data consolidation and analytical tasks.

E. Evaluation (Preliminary Findings)

As ITB's RDM prototype is still under active development, the present study emphasizes design validation rather than operational validation. The current evaluation focuses on institutional readiness and conceptual soundness, based on stakeholder feedback and comparative benchmarking with TU Wien. A full assessment using the RDA FAIR Data Maturity Model will be conducted in the next phase once the system is deployed, enabling quantitative measurement across Findability, Accessibility, Interoperability, and Reusability dimensions.

(1) Usability: Researchers found the prototype intuitive, particularly the dashboard visualization.
(2) FAIR Maturity: The RDA FAIR Data Maturity Model provides a structured framework for assessing compliance with the FAIR principles through qualitative and quantitative indicators. Each dimension Findable, Accessible, Interoperable, and Reusable, will later be assessed using metadata completeness, identifier persistence, protocol openness, and documentation adequacy. A preliminary conceptual assessment indicates that ITB's prototype currently supports Findability and Accessibility through planned metadata harvesting, while Interoperability and Reusability will be strengthened during the next implementation phase.
(3) Adoption Readiness: Surveys, though limited in scale, suggested strong researcher interest (78% agree that RDM framework is urgently needed).
(4) Challenges: Persistent barriers include limited IT infrastructure investment and low data stewardship literacy among staff.

V. Discussion

A. Theoretical Contributions

This study contributes to the existing body of knowledge on Research Data Management (RDM) by extending institutional models into the context of developing universities. The proposed five-pillar framework—Policy & Governance, Infrastructure, Processes & Services, Trust & Quality, and Capacity Building—illustrates how FAIR principles can be translated into institutional practice. Rather than merely replicating European best practices, the framework adapts them to the Indonesian context, addressing local challenges such as fragmentation, limited interoperability, and low awareness. The primary theoretical contribution lies in expanding institutional RDM models into developing contexts, where empirical evidence remains scarce.

B. Practical Implications

For Institut Teknologi Bandung (ITB), the framework offers a realistic roadmap toward transparent and evidence-based research governance, aligned with Indonesia's Asta Cita and the BRIN Open Science Policy. The initial prototype implementation using open-source platforms (InvenioRDM, DBRepo, JupyterHub) highlights several practical benefits:

(1) Setting up support for automated data ingest processes, ranging from continuous data feeds (e.g., sensor measurements or harvesting from selected sources) to one-off uploads of datasets collected during research projects.
(2) Research data curation
(3) Business intelligence dashboards to support evidence-based strategic decision-making.

Beyond publication analytics, the framework also envisions reuse of experimental datasets generated within ITB facilities, for example, laboratory measurements or sensor-based observations from wet-lab experiments. Once curated with FAIR metadata, these institutional datasets can be securely shared among ITB researchers for secondary analysis or cross-domain studies without additional data-request procedures. This demonstrates the practical value of institutional data stewardship, ensuring that datasets produced under ITB's facilities remain accessible and reusable by its academic community.

Such demonstrations, once implemented, are expected to illustrate how the framework can translate raw repository data into actionable insights for institutional leaders, supporting alignment with ITB's Research Roadmap 2025–2050.

Although preliminary, these tools have the potential to enhance ITB's competitiveness, transparency, and accountability to both internal and external stakeholders.

C. Challenges and Barriers

Despite the promising early results, several barriers must still be addressed:

1. **Infrastructure fragmentation** – decentralized faculty-level repositories hinder interoperability.
2. **Human capacity** – FAIR literacy and data stewardship expertise remain limited among researchers and staff.
3. **Financial investment** – sustainable infrastructure requires adequate funding for servers, security, and certifications such as CoreTrustSeal.
4. **Cultural change** – shifting from individual ownership of research data to institutional stewardship demands significant adaptation in mindset and practice.

D. Regional and Global Relevance

The proposed framework also carries regional and international relevance. As ITB advances toward FAIR-compliant RDM, it has the potential to serve as a reference model for Indonesian and Southeast Asian universities. Implementing this framework translates to an alignment with the ASEAN Open Science initiatives [16] and foster collaboration with Horizon Europe, thereby enabling ITB and Indonesia to strengthen their position themselves within global open science ecosystems.

VI. Conclusion and Future Work

This paper proposed a FAIR-compliant Research Data Management (RDM) framework for Institut Teknologi Bandung (ITB), adapted from TU Wien's best practices. The five-pillar model—Policy & Governance, Infrastructure, Processes & Services, Trust & Quality, and Capacity Building—provides a structured roadmap for institutional FAIR adoption. An open-source prototype (InvenioRDM, DBRepo, JupyterHub) demonstrates its feasibility for automated data harvesting, research mapping, and analytics, contributing to improved transparency and competitiveness within Indonesia's innovation agenda.

Future work will include pilot implementation across ITB faculties, integration with national and ASEAN Open Science platforms, and pursuit of CoreTrustSeal certification. Advanced analytics and international collaborations will further enhance interoperability and sustainability, positioning ITB as a model for FAIR-compliant RDM in Southeast Asia.

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