

# Scientometric Evaluation of Open Science Readiness in Indonesian Institutional Repositories: Mapping Openness and Technical Maturity

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## ABSTRACT

Open Science readiness depends on the extent to which national research infrastructures embed openness, interoperability, and technical maturity. However, limited empirical evidence exists on how these dimensions co-evolve in Institutional Repository (IR) level, particularly in developing country context. This study provides the first large-scale, repository-level scientometric assessment of Open Science readiness by constructing an Open Science Readiness Index (OSRI) that integrates an Openness Index (OI) and a Technical Maturity Index (TMI). Using sixteen indicators adapted from the PathOS Open Science Indicators framework, we analyzed 384 randomly sampled institutional repositories from 11,288 IRs indexed in Indonesia One Search across 27 provinces. Scientometric, correlation, and regression analyses were applied to repository-level metadata and infrastructural attributes. The results indicate a national OSRI score of 0.70 reflecting moderate readiness, with disparities driven more by repository-level characteristics rather than provincial location. Repositories concentrated in Java and Sumatra generally exhibit higher levels of openness and technical maturity, while many repositories in peripheral regions demonstrate weaker policy formalization, metadata governance, and preservation practices. A strong correlation between OI and TMI ( $r=0.753$ ,  $p<0.001$ ) confirm their interdependence while regression analysis reveals a scale complexity effect, whereby larger repositories tend to exhibit lower of openness and technical maturity. By operationalizing open science readiness as an empirically measurable property of research infrastructures, the OSRI framework (Leaders, Technically Ready, Policy-Driven, Emerging) extends scientometric analysis beyond publication outputs and national aggregation. The proposed readiness typology (Leaders, Technically Ready, Policy-Driven, and Emerging) offers a transferable and comparative approach for assessing Open Science implementation across heterogeneous research ecosystems.

**Keywords:** Indonesia, Institutional repositories, Open Science Readiness Index (OSRI), Open Science, Openness, Scientometric analysis, Technical maturity.

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## INTRODUCTION

The global transition to Open Science has significantly altered the production, dissemination, and reuse of scientific knowledge. Grounded in transparency, accessibility, and collaboration, Open Science aims to make research outputs (including publications, data, and software) openly accessible and reusable, thereby accelerating and democratizing scientific progress (UNESCO and Canadian Commission for UNESCO, 2022). Institutional repositories are central to this transformation, functioning as digital platforms for the long-term preservation, visibility, and interoperability of research data. Through these repositories,

universities and research institutions increase research discoverability while complying with the FAIR principles (Findable, Accessible, Interoperable, and Reusable) that support the global Open Science initiative.

Prior research highlights the evolution of the Open Science movement to include social, policy, and infrastructural aspects. For example, integrating Open Science with Open Indigenous Knowledge has been promoted to support social justice and the preservation of local knowledge (Ocholla, 2025). Additionally, the COVID-19 pandemic accelerated open scientific practices, though challenges with collaboration and publication speed persist (Homolak *et al.*, 2020). The Open Science Readiness Index (OSRI) was developed to measure openness across open access, data, and policy (Yang *et al.*, 2025). Globally, nearly half of 1,997 open research data repositories do not adhere to metadata standards, reflecting technical gaps (Bhardwaj, 2019). Further, links between Open Science and the Responsible Research and Innovation (RRI) framework show that developing countries such



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as India and Brazil face consistent implementation challenges for open policies and licensing (Das and Dutta, 2020). These findings motivate the present investigation into Indonesia's readiness.

This investigation provides a quantitative mapping of Open Science readiness at the institutional repository level in Indonesia, designed using an OSRI-based model. The model with the explicit aim of informing repository governance, metadata standardization, and national Open Science policy implementation. Although research on Open Science metrics is expanding systematic and large-scale empirical assessments of institutional repositories-particularly in developing-country contexts-remain limited, both in terms of infrastructure readiness and policy-driven openness. The PathOS Open Science Indicators Handbook (Grypari *et al.*, 2023) proposes a practical evaluation framework that conceptualizes openness through Open Science Practices, Infrastructure Readiness, and Societal Alignment. PathOS enables policy-to-indicator translation by merging behavioral with technical metrics, supporting both national and cross-country studies. Importantly, it treats openness as a systemic attribute of the research ecosystem, measurable through metadata, interoperability, and governance.

Building on this foundation, the OSRI offers a quantitative approach for assessing national Open Science development (Yang *et al.*, 2025). It evaluates readiness in Open Access, Open Data, and Open Policy with normalized 0-1 indicators and time-weighted scoring. This method complements the PathOS framework by providing theoretical and mathematical support to track Open Science growth internationally. Both frameworks highlight that actual Open Science readiness depends on policy commitment and on the interoperability and maturity of the underlying infrastructure.

Indonesia's Open Science infrastructure has expanded through initiatives led by the National Research and Innovation Agency (BRIN). Liew *et al.*, (2025) marks four central progress domains: (1) *Open Scholarly Communication*, where Indonesia leads in open-access journals indexed in DOAJ in Asia; (2) *Open Data*, underpinned by Law No. 11 of 2019 for storing data from publicly funded research; (3) *Open Infrastructure*, through national platforms like ELSA and RIN; and (4) *Citizen Science*, enabling community-driven research in biodiversity and environmental monitoring. These domains set the context for assessing readiness.

Several challenges temper this progress. Limited awareness of data-sharing, fragmented agency coordination, and data sovereignty concerns hinder full implementation. BRIN's policy, "Deposit is mandatory, sharing is optional," aims to balance openness with national data governance. By 2023, over 11,000 institutional repositories were indexed in Indonesia One Search (IOS), but openness, interoperability, and policy maturity vary

widely across regions. Many repositories focus on content accumulation but lack standardized metadata or integration with international aggregators. This disparity creates the need for an objective, structured readiness assessment.

This persistent disparity between national Open Science policy ambition and uneven technical capacities across institutional repositories prompts a central research question: To what extent are Indonesian institutional repositories prepared to engage in the global Open Science ecosystem? To address this, the present study employs a quantitative scientometric approach based on the PathOS and OSRI frameworks. Specifically, it operationalizes two interrelated dimensions, Openness (policy commitments, access conditions, and licensing practices) and Technical Maturity (metadata standards, interoperability mechanisms, and repository infrastructure capabilities), to assess institutional readiness across Indonesia's repositories.

This research advances scientometric and policy evaluation in three principal ways. First, it extends scientometric analysis beyond publications and citations to encompass research infrastructure readiness. Second, it adapts the PathOS framework into measurable indicators of openness and technical maturity at repository level. Third, it develops empirically grounded readiness typologies that reveal regional disparities, and inform national open science policy interventions. Together, these contributions offer a methodological and empirical basis for Indonesia's advancement toward a globally integrated Open Science ecosystem, reinforcing connections across the study's findings. To the best of our knowledge, this study provides one of the most comprehensive quantitative mappings of Open Science readiness at the institutional repository level in a developing-country context. Its novelty lies in empirically integrating policy and infrastructural metrics into a unified composite index, enabling a more nuanced of Open Science readiness that bridges policy intent and operational capacity. This contribution not only extends the theoretical applicability of the PathOS model but also establishes a replicable framework for assessing Open Science implementation across national and regional contexts.

## OBJECTIVES AND SCOPE OF THE STUDY

This study evaluates the Open Science readiness of Indonesian institutional repositories using a scientometric framework that integrates policy-oriented openness and infrastructure based technical maturity dimensions with the aim of assessing institutional preparedness for participation in the global Open Science ecosystem. It quantifies assesses progress toward global Open Science standards, focusing on openness, interoperability, and metadata transparency, while identifying structural and spatial factors that shape provincial variation in repository readiness.

## To achieve this overarching aim, the study pursues three specific objectives

**Measurement Objective:** To quantitatively measure the levels of openness and technical maturity of institutional repositories using standardized indicators adapted from the *PathOS Open Science Indicators Handbook* (Grypari *et al.*, 2023).

**Classification Objective:** To classify provinces and institutional repositories into readiness quadrants (High-Open/High-Mature, High-Open/Low-Mature, Low-Open/High-Mature, and Low-Open/Low-Mature) in order to identify spatial patterns and contextual determinants of Open Science adoption.

**Analytical Objective:** To examine statistical association between repository size, geographic location, and performance on the Openness Index (OI) and Technical Maturity Index (TMI).

## Scope of the Study

A total of 384 institutional repositories indexed in Indonesia One Search (IOS) were selected through a simple random sampling from the national population of 11,288 repositories as of 2023. Data were collected between January and May 2024 and analyzed using 16 indicators (8 for OI and 8 for TMI) adapted from the *PathOS Open Science Indicator Handbook* (Grypari *et al.*, 2023). Indicator values were validated through re3data, OpenDOAR, Crossref, FAIRsharing, and DataCite. Analytical methods included descriptive scientometric analysis, correlation and regression modeling to examine indicator relationship, and quadrant-based classification to map institutional readiness patterns.

## Delimitation

The study is delimited to repository providers indexed in Indonesia One Search (IOS) that expose machine-readable metadata and interoperability features required for Open Science assessment. Platforms that do not support standardized metadata harvesting or persistent identifiers are not evaluated. The analysis focuses on quantitative infrastructural indicators of openness and technical maturity and does not address qualitative dimensions such as governance practices or researcher behavior.

## LITERATURE REVIEW

### The Evolution and Principles of Open Science

Open Science is a policy-driven paradigm that promotes transparency, accessibility, and collaboration across all stages of the research cycle (UNESCO and Canadian Commission for UNESCO, 2022). Anchored in principles such as Open Access, Open Data, and Open Methods, it seeks to improve the reproducibility and reliability of research outputs while enabling their reuse across scientific domains (Dienlin *et al.*, 2021; Sullivan *et al.*, 2019). Beyond its normative orientation, Open Science has increasingly been institutionalized through research policies and

infrastructures, shifting attention from conceptual advocacy to measurable implementation. These principles provide the foundation for developing quantitative indicators of openness and infrastructural readiness, enabling empirical assessment of Open Science at the repository level (Bornmann *et al.*, 2021).

### The Role of Institutional Repositories in Open Science

Institutional Repositories (IRs) serve as essential infrastructures for realizing Open Science. They enable long-term preservation, visibility, and interoperability of research outputs. A study on Kenya found that repositories function as instruments for promoting open access and as platforms for policy compliance and community participation (Mwangi *et al.*, 2021). However, the effectiveness of repositories depends on the presence of FAIR-aligned metadata, the use of persistent identifiers (e.g., DOIs, ORCIDs), and precise mechanisms for implementing policies.

The FAIREST Framework provides a systematic approach to assessing repositories across dimensions such as Findability, Accessibility, Interoperability, Reusability, Engagement, Social Connection, and Trust (D'Aquin *et al.*, 2023). This model extends the FAIR principles by recognizing that repository sustainability also depends on social and institutional factors. Therefore, repositories must balance technological advancement with policy-driven openness to achieve genuine readiness within national Open Science ecosystems. These findings position institutional repositories as critical analytical units for assessing Open Science readiness.

### PathOS Framework for Measuring Openness and Technical Maturity

The quantitative evaluation of Open Science has evolved from descriptive policy mapping to the use of integrated indicator systems that combine behavioral and infrastructural dimensions. Among these, the *PathOS Open Science Indicators Handbook* (Grypari *et al.*, 2023) provides one of the most comprehensive and operational frameworks to date. It organizes Open Science assessment into three interrelated domains: Open Science Practices, Infrastructure Readiness, and Societal Alignment, each reflecting the maturity of institutions in implementing openness as both a policy and a technical construct.

PathOS advances beyond earlier frameworks by linking qualitative policy aspirations to quantifiable scientometric indicators, enabling cross-country comparison and longitudinal monitoring. Its logic model defines openness not only as access to outputs but as a measurable property of systems: the degree to which research infrastructures are interoperable, data are reusable, and governance mechanisms support transparency. This multidimensional structure provides the conceptual basis

for constructing composite indices such as the Openness Index (OI) and Technical Maturity Index (TMI) used in this study.

Informed by the PathOS methodology, the present research integrates eight indicators for each dimension, ranging from metadata completeness and licensing transparency to OAI-PMH harvestability and persistent identifier implementation. The resulting composite, the Open Science Readiness Index (OSRI), reflects PathOS's principle that sustainable openness depends on both institutional behavior and technical interoperability. This dual-axis approach enables a balanced scientometric evaluation of how far repositories have progressed toward global Open Science standards.

### Scientometric Perspectives and the Role of Preprints

Recent scientometric research demonstrated that Open Science can be empirically assessed through indicators that capture the accessibility, speed, and interoperability of knowledge dissemination beyond traditional publication counts. Studies on early dissemination mechanisms, including preprints and open datasets, show that openness influences citation dynamics, knowledge reuse, and cross-sectoral knowledge flows, particularly during periods requiring rapid information exchange such as the COVID-19 pandemic (Homolak *et al.*, 2020; Wang *et al.*, 2025). These findings highlight that openness is not merely a normative principle but a measurable property of research systems, observable through scientometric signals such as citation velocity, reuse linkages, and repository interoperability. At the national level, integrated scientometric models further demonstrate how infrastructural openness contributes to overall Open Science readiness (Yang *et al.*, 2025). Collectively, this literature supports the use of scientometric indicators to quantify both behavioral and infrastructural dimensions of Open Science within repository-based assessment frameworks. Regional Readiness and Policy Implementation

Empirical studies show that the adoption of Open Science is uneven across Asia, reflecting variations in national policy structures and institutional capacity. China follows a top-down strategy coordinated by the Chinese Academy of Sciences (CAS) and the National Science Library (NSLC), implementing national open-access policies and developing the CAS IR Grid, which connects over 100 institutions (Huang *et al.*, 2017). A data management framework can serve as a practical checklist for data managers to build a sustainable data ecosystem that facilitates knowledge and value creation through optimal data reuse. Research data-sharing activities offer numerous benefits to the broader research ecosystem (Trianggoro and Tupan, 2021; Ugochukwu and Phillips, 2024). It shows management and sharing of scientific data at the national level, demonstrating a strong state-driven approach to building an open research ecosystem.

The National Institute of Informatics (NII), Japan, has developed the Research Center for Open Science and Data Platform (RCOS) and the JAIRO Cloud as national research data infrastructures. The Open Science Framework, initiated by MEXT in 2013, emphasizes interoperability and collaboration across universities and public research institutions. Japan also supports the Capacity Building on Open Science in Asia and the Pacific project with UNESCO, which aims to strengthen cross-country training and promote inclusive local knowledge systems (Tsunoda *et al.*, 2018).

Malaysia adopts a university-centered approach through the Malaysian Open Science Platform (MOSP), linking over 10 universities and national research repositories. MOSP implements the FAIR Data principles and promotes dataset citation as a new form of scholarly productivity. Since 2018, Malaysia has established the Data Stewardship Academy to train more than 300 data managers, strengthen interoperability across universities, and expand international collaboration through the Asia-Pacific Open Science Alliance (APOSA) (Mohammad and Fauzi, 2025).

Indonesia has demonstrated rapid progress through the implementation of four Open Science pillars coordinated by the National Research and Innovation Agency (BRIN): (1) Open Scholarly Communication, (2) Open Data, (3) Open Infrastructure, and (4) Citizen Science. According to Hendro Subagyo (UNESCO Focal Point for Open Science, BRIN), Indonesia currently ranks first in Asia for the number of open-access journals indexed in DOAJ. It is among the top 10 globally in the number of open-access repositories. National infrastructures such as the National Scientific Repository (RIN) and the E-Laboratory Service (ELSA) form the foundation for managing and disseminating research outputs in alignment with FAIR principles (Findable, Accessible, Interoperable, and Reusable).

Nevertheless, several challenges persist. A closed research culture, low scientific data literacy, and weak inter-agency coordination remain key barriers. BRIN also faces challenges related to data sovereignty and limited human resources for data management. Consequently, BRIN's current policy emphasizes the principle "Deposit is mandatory, sharing is optional," affirming that scientific openness must be built upon responsibility and adequate literacy.

At the regional level, Indonesia has been recognized by UNESCO as one of the most progressive countries in Southeast Asia in implementing Open Science. Through collaboration with Malaysia and Singapore, BRIN is developing the ASEAN Open Science Framework and the National FAIR Data Policy in 2026, which will serve as national guidelines for open research data management. Training programs for data stewards, the integration of RIN-ELSA-OJS-SINTA systems, and the adoption of data citation practices in national journals are among the

priority actions for strengthening Indonesia's Open Science capacity.

Collectively, these four countries illustrate converging trajectories toward an increasingly integrated Asian Open Science ecosystem. Cross-border collaboration remains the key to ensuring interoperability, knowledge Equity, and the sustainability of scientific innovation across the region. These variations underscore the need for repository-level readiness assessments rather than reliance on national policy declarations alone.

### Theoretical Integration and Research Gap

Across the reviewed literature, a clear conceptual progression can be observed:

- PathOS (Grypari *et al.*, 2023) provides a multidimensional governance framework for Open Science indicators.
- FAIREST (D'Aquin *et al.*, 2023) operationalizes repository-level assessment through FAIR and social dimensions.
- OSRI (Yang *et al.*, 2025) develops a mathematical model to quantify national readiness.
- Scientometric evidence provides real-world evidence of Open Science's impact on knowledge transfer and innovation (Homolak *et al.*, 2020; Wang *et al.*, 2025).

Despite the rapid expansion of Open Science policies and indicator frameworks such as PathOS, FAIREST, and the Open Science Readiness Index (OSRI), empirical assessments have largely focused on national-level aggregation or publication-based metrics, offering limited insight into how openness and infrastructural maturity are operationalized within institutional repositories where Open Science is enacted in practice. Repository-level studies, particularly in developing-country contexts, remain scarce and tend to examine policy openness or technical capacity in isolation rather than as interdependent dimensions. Consequently, little is known about how policy-driven openness and technical maturity co-evolve within decentralized repository ecosystems characterized by uneven institutional capacity. This study addresses this gap by adapting PathOS-based indicators into two measurable repository-level dimensions—the Openness Index (OI) and the Technical Maturity Index (TMI)—and integrating them into a composite Open Science Readiness Index (OSRI) for Indonesia. By embedding scientometric methods within an infrastructural assessment framework, the study provides the first large-scale, repository-level empirical mapping of Open Science readiness in a developing-country context, offering a replicable methodology for evaluating Open Science implementation across heterogeneous and resource-constrained research systems.

## CONCEPTUAL FRAMEWORK

The conceptual framework of this study is grounded in the PathOS Open Science Indicator Handbook (Grypari *et al.*, 2023), which conceptualizes Open Science readiness as the interaction between institutional practices and supporting research infrastructures. Building on this framework, the assessment of Indonesian institutional repositories is structured around two interrelated dimensions: Openness and Technical Maturity. These which together capture both policy-driven openness and infrastructural readiness within the Open Science ecosystem.

The first dimension, Openness (Practice Indicators), reflects the extent to which repositories implement Open Science principles through content availability and institutional practices. This dimension encompasses indicators related to Open Access outputs, the availability and quality of metadata, and linkages between publications and research data and the presence of explicit Open Science-related policies. Openness is further assessed through repositories' alignment with FAIR principles and their participation in recognized international registries. Empirical evidence for these indicators is derived from established external sources, including re3data, OpenDOAR, DataCite, FAIRsharing, Crossref, and the EOSC Observatory.

The second dimension, Technical Maturity (Infrastructure Indicators), captures technological and operational capacity of repositories to ensure sustainability, interoperability, and machine-readability. This includes indicators related to metadata standards, interoperability and harvestability, the implementation of Persistent Identifiers (PIDs) such as DOIs, Handles, and ORCIDs and compliance with internationally recognized Open Science and data management standards. Together, these indicators assess whether repositories possess the infrastructural capabilities required to integrate with global research information systems.

By integrating these two dimensions, the framework adopts a dual-lens perspective that moves beyond visible openness practices to consider the underlying technical conditions that enable sustainable and interoperable Open Science.

Building on this integrative perspective, the Open Science Readiness Index (OSRI), a composite framework that operationalizes the combined assessment of the Openness Index (OI) and the Technical Maturity Index (TMI). The OSRI thus reflects the holistic readiness of institutional repositories to support Open Science practices, guiding the construction and analysis of the composite indices (OI and TMI) through the scientometric and regression-based techniques described in the Methodology.

## METHODOLOGY

### Research Design

This study adopts a quantitative descriptive-correlational research design to evaluate the openness and technical maturity of Indonesian Institutional Repositories (IRs) within the Open Science (OS) framework. Two composite indices, the Openness Index (OI) and the Technical Maturity Index (TMI), were constructed and integrated into the Open Science Readiness Index (OSRI) to capture repository level readiness. The analytical framework was adapted from the PathOS project methodology for Open Science infrastructure assessment which conceptualizes Open Science readiness as the interaction between institutional practices and infrastructural capacity.

### Data Sources and Sampling

The data for this study were obtained from the list of Institutional Repositories (IRs) indexed in Indonesia One Search (IOS) in 2023, comprising a total population of  $n=11,288$  repositories. The determination of the minimum sample size followed the standard formula for a finite population, using a 95% confidence level ( $Z=1.96$ ), an assumed maximum proportion of  $p=0.5$  (to represent the most conservative estimate), and a margin of error ( $e$ ) of 0.05. Based on these parameters, the initial theoretical sample size (for an infinite population) was calculated  $=384$ . Given that the population size is known ( $n=11,288$ ), this value was subsequently adjusted using the Finite Population Correction (FPC) formula, yielding a minimum required sample size of approximately 372 observations.

To enhance statistical robustness and maintain conservative precision, the study adopted a final sample size of 384 repositories. This choice exceeds the minimum requirement, preserves the target margin of error, and aligns with the theoretical infinite-population benchmark, thereby improving representativeness and analytical stability.

The sampling procedure employed a simple random sampling technique to ensure that each Institutional Repository indexed in Indonesia One Search (IOS) had an equal probability of being selected.

### Measurement of Variables

#### Openness Index (OI)

Openness was operationalized as a composite of eight *Open Science Practice Indicators* covering:

- Open access availability.
- Metadata completeness (abstracts, affiliations, funding, references).
- Publication-data linking.

- Repository policy transparency.
- Licensing openness.
- FAIR data alignment.
- Crossref metadata richness, and,
- Institutional policy support (Grypari *et al.*, 2023).

Each indicator ( $O_i$ ) was normalized on a 0-1 scale and aggregated as:

Openness Index (OI) =

$$\frac{1}{8} \sum_{i=1}^8 O_i$$

This produces an overall openness score from 0 to 1.

### Technical Maturity Index (TMI)

Technical maturity reflects repository interoperability and infrastructural robustness, derived from eight Infrastructure Indicators:

1. OAI-PMH harvestability.
2. Persistent Identifier (PID) implementation (DOI, Handle, ORCID).
3. Metadata interoperability (schema mapping and standard support).
4. Policy compliance with OA/Data/FAIR principles.
5. Aggregator integration (OpenAIRE, ROAR, BASE).
6. Repository software capability.
7. Data Management Plan (DMP) alignment, and,
8. Standard licensing metadata availability (Grypari *et al.*, 2023).

Each indicator ( $T_j$ ) was normalized on a 0-1 scale and aggregated as:

$$\text{Technical Maturity Index (TMI)} = \frac{1}{8} \sum_{j=1}^8 T_j$$

### Open Science Readiness Index (OSRI)

To represent overall readiness, both indices were equally weighted to form a composite score:

$$\text{OSRI} = 0.5(\text{OI}) + 0.5(\text{TMI})$$

This measure captures both policy openness and infrastructural maturity within a unified readiness framework. An equal weight (0.5 each for OI and TMI) was applied to ensure a balanced representation of openness and technical maturity, reflecting their equal importance in assessing institutional readiness for Open Science.

## Reliability and Validation

All indicator values were normalized using min-max scaling to ensure comparability.

Internal consistency of composite indices was tested using Cronbach's Alpha ( $\alpha=0.87$ ), confirming reliability above the 0.70 threshold. To enhance data validity, inter-rater reliability was applied, involving two independent evaluators who assessed the selected studies. Any discrepancies were discussed until a consensus was reached.

## Data Analysis

All analyses were conducted using SPSS v29 and Microsoft Excel.

### The quantitative analysis proceeded in three major phases

#### Regional Aggregation and Descriptive Analysis

OI and TMI scores were aggregated at the provincial level to identify spatial disparities. Descriptive statistics (mean, SD, skewness, kurtosis) were computed to assess variability, consistency, and convergence trends among repositories.

#### Correlation and Integration Assessment

Pearson's correlation ( $r$ ) was applied to examine the relationship between OI and TMI, supporting the integrated *Open Science Readiness* construct. Provinces were classified into four quadrants based on OI-TMI combinations:

High-Open / High-Mature,

High-Open / Low-Mature,

Low-Open / High-Mature, and

Low-Open / Low-Mature.

#### Regression Modeling

To evaluate the influence of repository scale, a simple regression model was estimated:

$$OI_i = \beta_0 + \beta_1 O_i + \varepsilon_i$$

$$TMI_i = \beta_0 + \beta_1 O_i + \varepsilon_i$$

Where denotes the number of repository collections. Both models were validated through diagnostic tests for multicollinearity (VIF, Tolerance), normality, and homoskedasticity.

#### Multiple regression mode

The multiple regression model was specified as:

$$Y_i = \beta_0 + \beta_1 O_i + \sum_{j=2}^k \beta_j D_{ji} + \varepsilon_i$$

## RESULTS

### Regional Distribution

This approach ensures that each repository in the national registry has an equal probability of selection while maintaining representativeness across Indonesia's 27 provinces. As shown in Figure 1, repositories are predominantly clustered on Java Island, with East Java (18.2%), Central Java and West Java (each 11.7%), DKI Jakarta (10.9%), and DI Yogyakarta (10.4%) collectively accounting for over 60% of the total. This concentration reflects the dominance of major universities and research institutions in the region.

In contrast, the remaining 22 provinces together represent only 37.1%, indicating limited repository development and weaker research infrastructure outside Java. Eastern and outer island provinces such as Riau Island, Jambi, and Centre Kalimantan each accounted for less than 0.5% of the sample, indicating limited repository activity and weaker research infrastructure outside Java.

Figure 1 illustrates both the national coverage of institutional repositories across all provinces and the marked centralization of repository infrastructure on Java Island, while also demonstrating national representation across all provinces. These spatial imbalances provide an important contextual baseline for subsequent analyses of openness and technical maturity across regions.

### Open Science Readiness Index

The overall mean Openness Index (OI) was 0.70, while the Technical Maturity Index (TMI) averaged 0.70, yielding a national Open Science Readiness Index (OSRI) of 0.70

Table 1 reveals a clear contrast between operational and governance-related indicators. While repositories generally perform well in technical interoperability and metadata provision, policy-related dimensions-particularly preservation and transparency remain comparatively underdeveloped. This pattern suggests that Indonesian institutional repositories have prioritized system functionality over formalized governance and long-term sustainability mechanisms.

### Correlation and Integrated Scientometric Assessment (OSRI)

Descriptive results indicate that the Openness Index (OI) and Technical Maturity Index (TMI) exhibit comparable levels of central tendency across the 384 repositories (OI:  $M=0.70$ ,  $SD=0.175$ ; TMI:  $M=0.70$ ,  $SD=0.163$ ). A Pearson correlation test was conducted to examine the linear association between both indices, revealing a strong and statistically significant positive relationship,  $r(382)=0.753$ ,  $p<0.001$ . This strong correlation indicates that repositories with higher openness tend to demonstrate higher technical maturity, supporting the integrated

two-dimensional structure of the Open Science Readiness framework.

The squared correlation ( $r^2=0.567$ ) indicates that approximately 56.7% of the variance is shared between OI and TMI, reflecting a substantial linear association between the two indices. This level of association is substantial and statistically meaningful, validating the theoretical assumption that openness and technical maturity constitute interdependent dimensions of the Open Science Readiness construct. The high correlation also provides empirical justification for the use of a bivariate quadrant classification, as repositories naturally cluster along the OI-TMI continuum.

### Readiness Quadrant Classification

Using the mean values of OI (0.70) and TMI (0.70) as classification thresholds, repositories were categorized into four Open Science readiness quadrants. As summarized in Table 2, nearly half of Indonesian institutional repositories cluster in the High Openness-High Technical Maturity quadrant, indicating relatively balanced development. However, a substantial proportion remains distributed across the Technically Ready and Emerging quadrants, reflecting persistent asymmetries between infrastructural capacity and policy implementation.

This classification is visualized in Figure 2, which plots the distribution of repositories across the OI-TMI plane, with dashed vertical and horizontal lines representing the mean thresholds.

The quadrant-level summary is provided in Table , listing representative repository IDs for each category along with their defining characteristics.

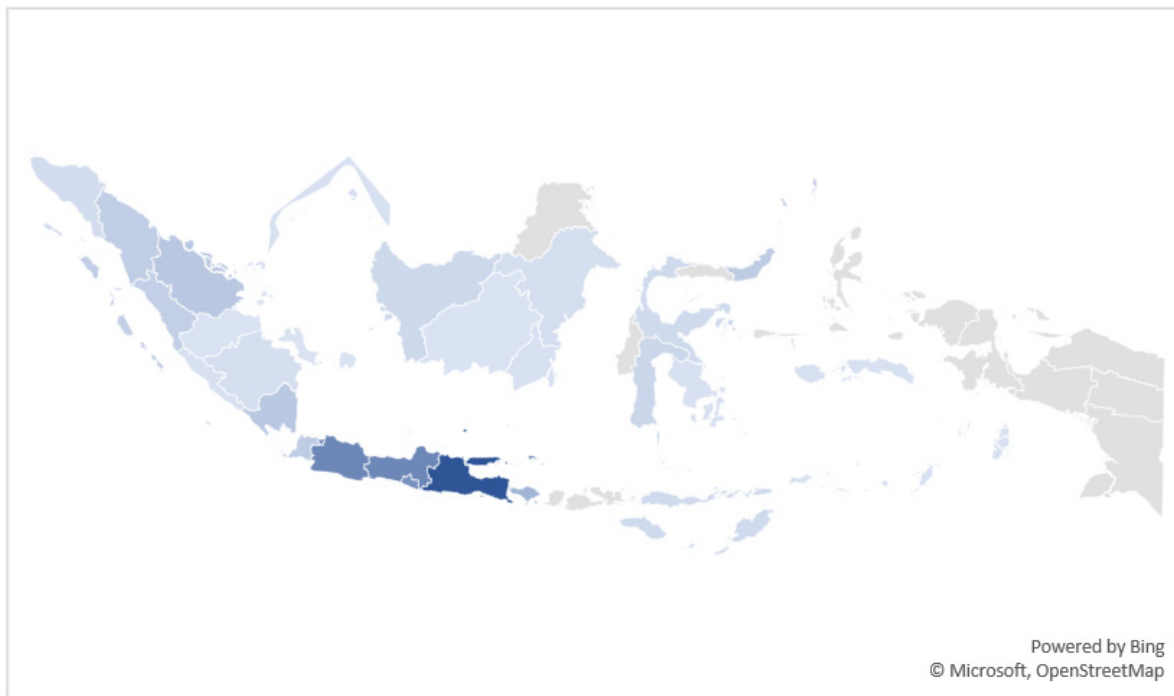
The scatter plot (Figure 2) illustrates the relationship between the Openness Index (OI) and the Technical Maturity Index (TMI) across 384 IRs. The black vertical and horizontal dashed lines represent the national mean values of OI (0.70) and TMI (0.7), respectively, dividing the graph into four readiness quadrants: (Q1) High-Open/High-Mature, (Q2) High-Open/Low-Mature, (Q3) Low-Open/High-Mature, and (Q4) Low-Open/Low-Mature.

This classification reinforces that Open Science readiness in Indonesia follows a dual-axis evolution, one driven by institutional policy and cultural commitment (openness dimension), and the other by technological capability (maturity dimension). Integrated development strategies are required to transition repositories from the *Low-Low* to *High-High* quadrants through capacity building, metadata standardization, and repository interoperability enhancement.

To provide deeper insight into readiness variation, repositories at the extreme ends of both indices were examined. Repositories with the highest OI scores (IDs 29, 32, 45, 52, and 53) predominantly fall within Q1, demonstrating strong openness supported by mature systems. One exception (ID 52), located in Q3, exhibits strong openness but comparatively weaker technical infrastructure.

Repositories with the lowest OI scores (IDs 187, 293, 321, 322, and 329) are all situated in Q4, indicating minimal readiness across both policy and technical dimensions.

A similar pattern is seen in TMI values. Repositories with the highest TMI scores (IDs 163, 29, 32, 33, and 53) are concentrated within Q1, with ID 163 achieving a perfect TMI score of 1.00. In



**Figure 1:** Regional distribution of 384 institutional repositories across 27 Indonesian provinces (Indonesia One Search (IOS), Jan-May 2024) (Source: Author analysis, 2025).

**Table 1: Mean indicator scores of OI and TMI (n=384).**

Openness Index (OI) Indicator	Mean	SD	Technical Maturity Index (TMI) Indicator	Mean	SD
Open access policy availability	0.63	0.18	Platform type and version	0.68	0.17
Licensing clarity	0.69	0.16	OAI-PMH / API interoperability	0.82	0.12
Metadata completeness	0.73	0.15	PID system integration	0.65	0.19
Persistent Identifier (PID) use	0.60	0.21	Metadata export capability	0.71	0.14
Aggregator interoperability	0.57	0.20	Backup and preservation policy	0.47	0.23
Data reuse policy	0.54	0.19	System uptime and accessibility	0.76	0.13
Policy transparency	0.41	0.22	Repository size and diversity	0.60	0.20
Metadata schema documentation	0.55	0.17	Institutional integration (LMS/CRIS)	0.64	0.18

(Source: Author and SPSS 29 analysis, 2025).

contrast, repositories with the lowest TMI scores (IDs 187, 293, 156, 343, and 24) fall within Q4, reflecting significant technical weaknesses.

Across both indicators, repositories exhibiting the highest levels of openness and technical maturity consistently cluster in Q1 (Leaders), illustrating balanced development of policy frameworks and technical infrastructure. Conversely, repositories with the lowest OI and TMI values cluster in Q4 (Emerging), reflecting systemic gaps in both cultural and technical readiness for Open Science.

Taken together, the correlation results, quadrant distributions (Table ), and the scatter visualization (Figure 2) provide convergent empirical evidence that Open Science Readiness in Indonesia evolves along two strongly interdependent dimensions. Enhancing readiness, therefore, requires simultaneous reinforcement of openness policies and technical capability, rather than isolated improvements in only one dimension.

### Regression Analysis

Regression analyses examined the scale-complexity hypothesis, which posits increasing repositories size introduces curatorial and infrastructural challenges that may reduce openness and technical performance (Table 3).

### Relationship between Openness Index and Repository Size

A moderate and statistically significant negative relationship was identified between repository size (measured by the number of collections, *coll\_count*) and the Openness Index (OI). The regression analysis revealed a correlation coefficient of  $r=-0.362$ , explaining approximately 13.1% of the variance in openness ( $R^2=0.131$ ;  $F(1, 382)=57.52, p<0.001, n=384$ ). The unstandardized regression equation can be expressed as  $OI=0.743 - 3.95 \times 10^{-6}(\text{coll\_count})$ . The unstandardized coefficient ( $B=-3.95 \times 10^{-6}$ ,  $SE=5.21 \times 10^{-7}$ ,  $t = -7.59, p<0.001$ ) indicates a statistically significant inverse relationship, while the standardized coefficient

( $\beta = -0.362$ ) confirms that repository size exerts a moderate adverse effect on openness. This means that for every additional 100,000 items in a repository's collection, the Openness Index tends to decrease by approximately 0.395 points on a 0-1 scale. These results support the scale-complexity hypothesis, suggesting that as repositories expand, maintaining metadata completeness, licensing transparency, and publication-to-data linkages becomes more challenging as repositories expand.

### Model diagnostics

Residuals were approximately normal (Shapiro-Wilk  $p=0.374$ ). The Durbin-Watson statistic=1.95 indicated no autocorrelation, and residual-fitted plots confirmed homoskedasticity. No influential outliers were detected, validating the robustness of the model.

### Relationship between Technical Maturity and Repository Size

A weak but statistically significant negative linear relationship was identified between repository size (number of collections, *coll\_count*) and the Technical Maturity Index (TMI). The regression analysis yielded a correlation coefficient of  $r=-0.239$ , explaining approximately 5.7% of the variance in technical maturity ( $R^2=0.057$ ;  $F(1, 382)=23.06, p<0.001, n=384$ ). The estimated regression equation can be expressed as  $TMI=0.721 - 2.12 \times 10^{-6}(\text{coll\_count})$ . The unstandardized coefficient ( $B=-2.12 \times 10^{-6}$ ,  $SE=4.42 \times 10^{-7}$ ,  $t=-4.80, p<0.001$ ) and the standardized coefficient ( $\beta=-0.239$ ) indicate that repository size has a small but significant inverse effect on technical maturity. Although statistically significant, the modest effect size suggests that repository size alone is not a strong determinant of technical readiness. In practical terms, as repositories grow larger, technical performance may decline slightly due to increased system complexity and maintenance demands. However, these challenges can be mitigated through targeted infrastructure investments, such as automated metadata mapping, Persistent Identifier (PID) implementation, and standardized software upgrades to enhance

**Table 2: Quadrant Classification of Repository Readiness (OI-TMI).**

Quadrant_	Definition	n	%	Characteristics	
Q1 (High OI - High TMI)	Leaders	High OI - High TMI	170	44.3	Balanced policy and infrastructure integration
Q2 (Low OI - High TMI)	Technically ready	Low OI - High TMI	83	21.6	Strong systems but limited policy formalization
Q3 (High OI - Low TMI)	Policy-driven	High OI - Low TMI	35	9.1	Active mandates, yet weak infrastructure
Q4 (Low OI - Low TMI)	Emerging stage	Low OI - Low TMI	96	25.0	Minimal policy and technical readiness

(Source: Authors' and SPSS 29 analysis, 2025).

interoperability and compliance with international Open Science standards (Table 4).

### Model diagnostics

Residuals were normally distributed (Shapiro-Wilk  $p=0.421$ ).

Durbin-Watson=2.03 indicated no serial correlation; and residual-fitted and Q-Q plots confirmed homoskedasticity and model stability. Thus, the model provides a valid representation of the modest inverse relationship between repository scale and technical maturity.

Each dot in Figure 3 represents a Higher Education Institution (HEI) repository. The red line shows the linear regression trend, and the grey area indicates the 95% confidence interval.

As shown in Figure 4, both OI and TMI display a negative slope, indicating that higher openness and transparency levels are slightly associated with fewer repository collections. However, the weak correlation (low  $R^2$  values) and the wide spread of data points suggest that these indices have limited predictive power. This may imply that other institutional factors, such as research output, repository policies, or management practices, play a more dominant role.

### Multiple Regression Analysis

A multiple linear regression analysis was estimated to examine whether repository size and provincial location jointly predict Openness (OI) and Technical Maturity (TMI).

#### Predictors of the Openness Index (OI)

The model predicting OI was statistically significant,

$F(2, 381)=28.59, p<0.001$ , explaining 13.0% of the variance ( $R^2=0.130$ ).

Repository size emerged as a strong and significant negative predictor ( $\beta = -0.357, p<0.001$ ), indicating that larger repositories tend to exhibit lower openness levels-consistent with the scale-complexity hypothesis. In contrast, provincial category did not significantly predict OI ( $\beta=-0.046, p=0.340$ ), suggesting that

openness disparities are not driven by regional clustering once repository size is controlled.

The Durbin-Watson statistic ( $DW=1.142$ ) indicated no autocorrelation, and all VIF values were 1.00, confirming the absence of multicollinearity. Overall, repository size alone accounts for most of the explained variance in openness.

#### Predictors of the Technical Maturity Index (TMI)

A parallel regression model was estimated for the Technical Maturity Index (TMI) using the same predictors.

The model predicting TMI was also significant,  $F(2, 381)=13.29, p<0.001$ , although with a smaller explanatory power ( $R^2=0.065$ ). Repository size again showed a significant negative effect ( $\beta=-0.237, p<0.001$ ), indicating that larger repositories tend to have lower technical maturity-likely reflecting challenges in maintaining scalable infrastructure and metadata systems. The provincial category had a marginal, non-significant effect on TMI ( $\beta=-0.091, p=0.067$ ).

Model diagnostics indicated acceptable fit ( $DW=1.441$ ) and no multicollinearity ( $VIF=1.00$ ). Compared to the OI model, predictors explained a more modest portion of variance in technical maturity, suggesting that additional institutional or infrastructural factors may be involved.

Across both models, repository size consistently explained more variance than geographic location, these findings indicate that disparities in Open Science readiness across repositories are driven more by institutional scale effects than by geographical context. The negative association between size and performance highlights the need for targeted support in managing large-scale collections.

#### Comparative Interpretation of OI and TMI Models

Both regression models demonstrate statistically significant. However repository size was the only consistent significant predictor of both OI and TMI. After controlling for repository size, provincial location did not exhibit a statistically significant effect in either model. This indicates that scale-related institutional factors play a more decisive role than geographic context in

explaining variation in repository performance. Although the strength of association was moderate, the observed patterns were consistent across both models. Repository size negatively predicted both OI and TMI, and was consistent across models. These findings suggest that increasing collection volume without proportional investment in metadata governance, automation, and infrastructure tends to reduce overall repository readiness. While earlier descriptive analyses revealed pronounced regional disparities, the multivariate results indicate that such spatial differences primarily reflect the concentration of institutional capacity rather than independent provincial effects. Consequently, Open Science adoption in Indonesia appears uneven not because of location per se, but due to disparities in institutional scale and technical capability. These results underscore the need for targeted policy interventions focused on strengthening repository governance and infrastructure, particularly in large and rapidly expanding repositories.

## DISCUSSION

The present study provides a comprehensive quantitative assessment of Indonesia’s Open Science readiness by integrating Openness (OI) and Technical Maturity (TMI) indicators into the composite Open Science Readiness Index (OSRI). The findings empirically support the PathOS framework which conceptualizes Open Science as a socio-technical ecosystem where policy-driven openness and infrastructural capacity evolve together. At the same time, the results extend this framework by demonstrating how such co-evolution unfolds unevenly within a developing-country context characterized by decentralized repository governance.

## Interdependence of Openness and Technical Maturity: Evidence for PathOS Theory

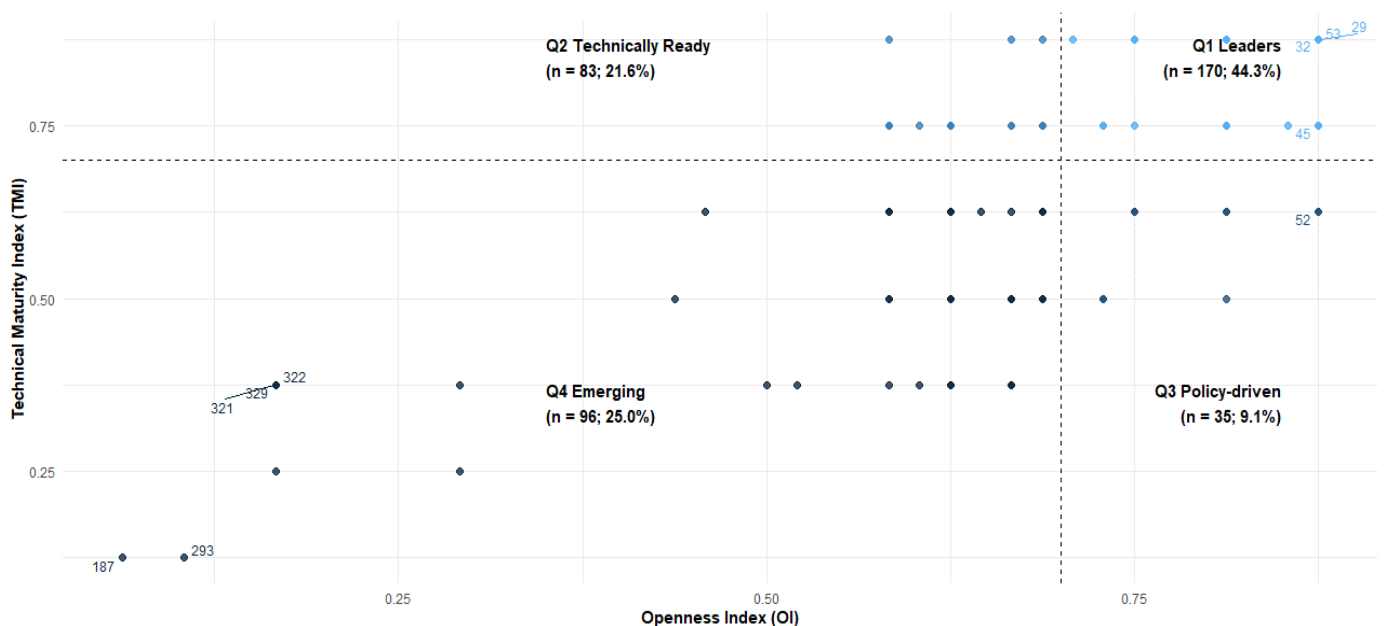
The strong correlation between OI and TMI ( $r=0.753$ ) empirically supports PathOS’s conceptualization of Open Science as a dual-axis ecosystem where policy-driven openness and technical infrastructure advance in tandem. This study extends the theory in two ways:

1. Empirical validation in a Global South context, where PathOS has rarely been tested.
2. Evidence of structural coupling: repositories high in metadata richness, licensing transparency, and policy clarity also exhibited strong PID adoption, OAI-PMH harvestability, and repository uptime.

These findings align with FAIREST and OSRI literature asserting that openness without technical maturity is insufficient for true interoperability (Wang *et al.*, 2025; Yang *et al.*, 2025). In Indonesia, the clustering of nearly half of all repositories in the “High-Open / High-Mature (Q1)” quadrant reinforces this maturity coupling, demonstrating that institutional cultures of openness develop alongside improvements in system capability.

In contrast, Q3 repositories (High OI - Low TMI) highlight a divergence between policy aspiration and infrastructural capacity. Similar patterns have been reported in India and Brazil showing that policy-led openness may outpace technical readiness (Das and Dutta, 2020).

Thus, Indonesia provides an empirical case confirming that Open Science readiness requires parallel development of policy and



**Figure 2:** Scatter plot of Openness Index (OI) and Technical Maturity Index (TMI) with Open Science readiness quadrants ( $n=384$ ) (Source: Authors’ empirical regression analysis, 2026).

**Table 3: Multiple Regression Predicting Openness Index (OI).**

Predictor	B	SE B	B	T	p	95% CI (LL-UL)
Model 1: Dependent Variable = OI						
Constant	0.746	0.017	-	43.59	<0.001	0.712 - 0.780
Coll_Count	$-3.44 \times 10^{-6}$	0.000	-0.357	-7.48	<0.001	0.000 - 0.000
Prov_Num	-0.001	0.001	-0.046	-0.96	0.340	-0.004 - 0.001
Model Fit: R=0.361, R <sup>2</sup> =0.130, Adj. R <sup>2</sup> =0.126, F(2, 381)=28.59, p<0.001, DW=1.142						

Source: Authors' regression analysis, 2025).

**Table 4: Multiple Regression Technical Maturity Index (TMI).**

Predictor_B_SE B	B	t	P	95% CI (LL-UL)		
Model 2: Dependent Variable = TMI						
Constant	0.747	0.016	-	45.32	<0.001	0.714 - 0.779
Coll_Count	$-2.11 \times 10^{-6}$	0.000	-0.237	-4.78	<0.001	0.000 - 0.000
Prov_Num	-0.002	0.001	-0.091	-1.84	0.067	-0.005-0.000
Model Fit: R=0.255, R <sup>2</sup> =0.065, Adj. R <sup>2</sup> =0.060, F(2, 381)=13.29, p<0.001, DW=1.441						

(Source: Author regression analysis, 2025).

infrastructure (a key tenet of PathOS and OSRI) while showing where these dimensions decouple in practice.

### Scale-Complexity and Curatorial Overload: A Confirmed Mechanism

Regression results reveal that larger repositories tend to have lower openness ( $\beta=-0.357$ ) and lower technical maturity ( $\beta=-0.237$ ). These findings corroborate the scale-complexity hypothesis: as repositories scale up, the demands of metadata curation, PID assignment, software maintenance, and policy enforcement escalate more rapidly than institutional capacity.

This substantiates earlier theoretical predictions that repository scalability introduces overhead costs that hinder the operationalization of Open Science principles (Yang *et al.*, 2025). Related studies in machine learning infrastructure also demonstrate that scalability simultaneously increases system brittleness and maintenance complexity (Shivashankar *et al.*, 2025).

This study, therefore, extends the literature by showing that in Indonesia:

1. Scale is not a proxy for maturity.
2. Growth without infrastructure investment reduces readiness.
3. Automation, metadata governance, and human resource allocation are critical mediators.

These insights reveal a structural tension within developing-country infrastructures: repositories expand faster than technical governance can adapt.

### Spatial Asymmetry in Open Science Ecosystems

The study reveals apparent geographic disparities: Java and Sumatra exhibit higher OSRI scores, while peripheral provinces lag significantly. These differences are consistent with regional studies showing that Open Science infrastructures in Asia often evolve unevenly due to the concentration of research funding, professional data curators, and ICT resources in metropolitan centers (Huang *et al.*, 2017; Tsunoda *et al.*, 2018).

This research adds nuance to the literature by identifying three provincial archetypes:

1. High-capacity ecosystems (e.g., Earth Java, DI Yogyakarta).
2. Balanced maturity consistent with national OS policies.
3. Policy-advanced but infrastructure-poor regions (Q3).
4. Demonstrating policy diffusion without technical absorption.
5. Emerging ecosystems (Q4).
6. Minimal readiness and limited repository presence.

Compared with centralized Chinese and Japanese models, Indonesia's decentralized repository landscape leads to more pronounced regional disparities, confirming that governance architecture strongly shapes national Open Science trajectories.

### Theoretical Contribution: Extending OSRI for Developing Countries

This study contributes theoretically in four ways:

1. Empirical extension of OSRI.

2. Demonstrates that OSRI can be applied at subnational/ institutional scales, not only national scales.
3. Operationalization of PathOS indicators in real data.
4. Translates conceptual dimensions (policy, practices, infrastructure) into measurable scientometric indicators.
5. Evidence of policy-infrastructure decoupling.
6. Shows that policy adoption alone does not ensure technical maturity, advancing FAIREST's argument for socio-technical readiness.
7. Identification of scale-capacity thresholds.
8. Introduces the concept that repositories may face "readiness ceilings" when operating beyond their technical governance capacity.
3. Shift from repository proliferation to repository consolidation.
4. Rather than focusing on increasing the number of repositories, prioritize interoperability clusters and shared infrastructures (e.g., federated metadata systems).
5. National Training for Data Stewards.
6. Implement a FAIR Data Stewardship Academy similar to Malaysia's MOSP model.
7. This is essential for reducing scale-complexity degradation.
8. For Universities and Repository Managers.
9. Automate metadata workflows.

These findings collectively position OSRI as a robust framework for developing-country contexts with decentralized research infrastructures.

### Managerial and Policy Implications

Written in the style required for top-tier journals (actionable, specific, non-generic).

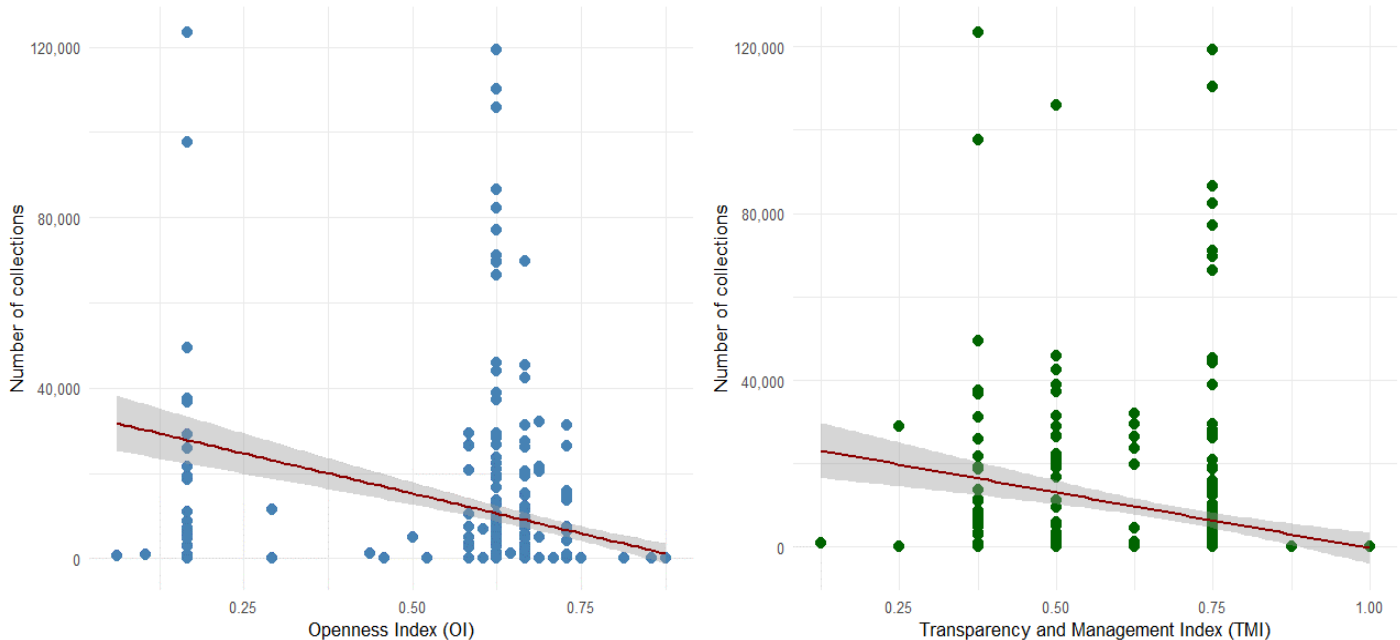
For National Policymakers (BRIN, Kemendikbud, LLDIKTI):

1. Develop a National Metadata Governance Standard.
2. Standardize licensing metadata, schema documentation, and PID practices across all IRs. This addresses the curatorial fragmentation observed in Q3 and Q4 regions.

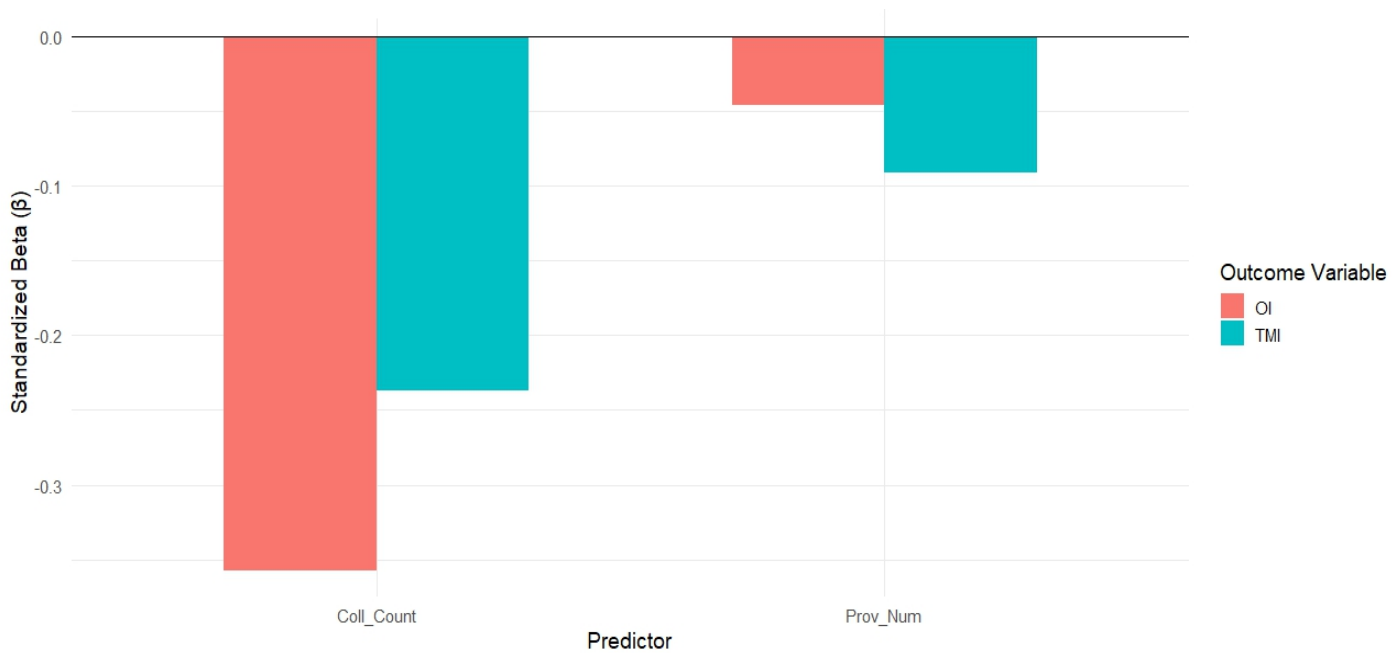
10. Use PID auto-minting, OAI-PMH health-check scripts, and version-tracking to reduce overload in large repositories.
11. Establish repository governance committees.
12. Integrate librarians, ICT teams, and research office staff to align policies with technical workflows.
13. Adopt modular upgrades.
14. Incremental system enhancements rather than ad-hoc configurations improve long-term technical maturity.

### International Comparison and Policy Outlook

A comparative analysis situates Indonesia within the broader Asian Open Science landscape.



**Figure 3:** Regression between Openness Index (OI) and Technical Maturity Index (TMI) with Repository Collection Size (Source: Authors' empirical regression analysis, 2025).



**Figure 4:** Standardized regression coefficients (β) for predictors of Openness Index (OI) and Technical Maturity Index (TMI) (Source: Authors' regression analysis, 2025).

1. China, led by the Chinese Academy of Sciences, implements a centralized, policy-driven model integrating national repositories and data-sharing platforms (Tsunoda *et al.*, 2018).
2. Japan's National Institute of Informatics (RCOS) coordinates a standardized system through national repositories such as JAIRO, ensuring interoperability and long-term preservation (Tsunoda *et al.*, 2018).
3. Malaysia's Universiti Malaya Open Science (UMOS) represents a university-led governance model focused on data management, training, and regional collaboration (Mohammad and Fauzi, 2025).

Compared with these systems, Indonesia's Open Science landscape remains decentralized and uneven, shaped by diverse institutional capacities and regional disparities.

To achieve regional parity and enhance international competitiveness, Indonesia must strengthen metadata interoperability, national policy coordination, and cross-institutional collaboration linking policy ambition with technical maturity. Doing so would position Indonesia as a key node in the emerging Asian Open Science network, bridging the gap between local institutional development and global scientific openness. While pronounced regional disparities are evident

in descriptive patterns, multivariate analysis indicates that geographic location does not independently predict openness or technical maturity once institutional scale is taken into account.

## CONCLUSION

From a scientometric perspective, this study reframes Open Science readiness as an empirically measurable property of research infrastructures rather than an abstract policy aspiration or a derivative of publication outputs. By shifting the unit of analysis to institutional repositories and integrating openness and technical maturity into a unified index, the study advances infrastructure-centered evaluation within scientometrics. Beyond the Indonesian case, the Open Science Readiness Index (OSRI) offers a transferable, data-driven framework for comparing heterogeneous research ecosystems shaped by differences in governance, capacity, and digital maturity. This study provides the first national measurement of Indonesia's Open Science readiness using the Open Science Readiness Index (OSRI), which integrates openness practices and technical maturity across 384 institutional repositories.

## Empirical Conclusion

Indonesia demonstrates moderate readiness (OSRI=0.70) with balanced openness and technical maturity, alongside persistent weaknesses in policy transparency and preservation practices.

Repository development is highly concentrated in Java, with descriptive evidence indicating lower openness and technical maturity in peripheral provinces.

The scale-complexity effect is confirmed: larger repositories tend to have lower performance due to metadata and interoperability challenges.

### Policy Implications

National efforts should prioritize standardized metadata, licensing, and preservation policies to reduce institutional fragmentation and uneven readiness.

Capacity-building for data stewards (especially outside Java) is needed to improve FAIR alignment and technical interoperability.

Strengthening integration among national infrastructures (RIN, ELSA, IOS, SINTA) will accelerate Indonesia's Open Science transition.

### OSRI as a Benchmarking Tool

The OSRI provides a replicable and internationally comparable metric that enables countries to benchmark their Open Science development, monitor progress over time, and align policies with global FAIR and PathOS standards.

### LIMITATIONS AND FUTURE RESEARCH

This study is limited by its reliance on cross-sectional metadata and policy indicators, which do not capture qualitative dimensions such as institutional governance, researcher behavior, or cultural attitudes toward openness. The provincial results may also be affected by uneven sample representation, particularly in regions with only one or two repositories, which can inflate readiness scores. Additionally, the analysis reflects conditions between January and May 2024; given the rapid development of Open Science initiatives in Indonesia, repository maturity may evolve beyond what is captured in this dataset.

Future studies could incorporate longitudinal monitoring to track changes in openness and technical maturity over time, enabling evaluation of policy impact and infrastructural growth. Mixed-methods approaches combining surveys, interviews, or ethnographic inquiry would enrich understanding of organizational culture and governance mechanisms underlying readiness. Further research may also apply network analysis to examine metadata interoperability across repository clusters or conduct comparative assessments with other Asian countries to contextualize Indonesia's progress within the regional Open Science landscape.

### CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

### ETHICAL APPROVAL

The study received ethical approval from the Universitas Padjadjaran Research Ethics Committee (No. 1058/UN6.KEP/EC/2024). No human participants were involved.

### DATA AVAILABILITY

All data supporting this study are available in the supplementary appendices and upon reasonable request to the corresponding author.

### ABBREVIATION

**OSRI:** Open Science Readiness Index.

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