Landscape Overview of Persistent Identifiers for Research Data Repositories

September 2024

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Introduction

Persistent identifiers (PIDs) are unique, long-lasting references that ensure the accessibility and citability of digital resources even if their location or metadata changes. PIDs are typically registered by institutions or organizations, motivated by the need to ensure data management consistency, improve the visibility of their resources, and support long-term preservation and access.

PIDs play a crucial role in ensuring the long-term accessibility, discoverability, and citation of research data. As the volume and diversity of research data repositories continue to grow, the discussion around a standardized PID for Research Data Repositories (RDRs) continues. This paper provides an overview of specific examples of PIDs for RDRs, outlining their characteristics followed by a discussion of what a PID for RDRs should be referencing.

Context

General

In the dynamic and ever-evolving landscape of scholarly communication, research data repositories (RDRs) serve more and more as pivotal components for storing, sharing, and preserving research outputs. This gives rise to the need for a persistent identifier (PID) for RDRs. The current re3data metadata schema supports several PIDs to describe different types of information (e.g., ROR ID for organizations, DOIs for datasets); however, a solution is lagging for the prominent use case of uniquely identifying RDRs themselves.

The context of this paper lies in outlining the current landscape of the use of PIDs for RDRs, as well as the characteristics of these PIDs. The paper does not claim to give a holistic survey of PIDs for RDRs but rather serves as a milestone in an ongoing discussion.

re3data COREF

Since January 2020, the German Research Foundation (DFG) has provided funding for the "re3data – Community Driven Open Reference for Research Data Repositories (COREF)" project initiated by re3data. The primary objective of this project is to progress and augment re3data, integrating it into the research infrastructure landscape as a central point of reference for RDRs and establishing connections with other relevant services. The project aims to enhance the re3data technical platform, making it more conducive to the retrieval of dependable and credible information in RDRs. Additionally, re3data seeks to evolve into a framework-as-a-service for third parties, enabling the development of applications, and promoting the utilization of re3data as a community-driven and authoritative source for reputable RDRs within the scientific community.

Work Package 1 of the re3data COREF project focuses on establishing a conceptual model for user stories.[1] Task 1.2.2, in particular, is dedicated to conducting a landscape overview of existing PID solutions for RDRs, with the overall goal of assessing and understanding the available solutions. This landscape overview is complementary to the results of a workshop series conducted in the re3data COREF project.[2]

The selection of PIDs to be included in this landscape overview is based on a quantitative analysis of the identifiers used in the re3data metadata schema field repositoryIdentifier: An identifier that refers to the RDR or a record describing the RDR (wrapper element).[3]

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[1] Vierkant, P., Bertelmann, R., Cousijn, H., Elger, K., Ferguson, L. M., Goebelbecker, H.-J., Kindling, M., Kloska, G., Nguyen Thanh, B., Pampel, H., Petras, V., Schabinger, R., Schnepf, E., Semrau, A., Strecker, D., Trofimenko, M., Ulrich, R., Upmeier, A., Weisweiler, N. L., … Witt, M. (2021). re3data Conceptual Model for User Stories. Re3data. https://doi.org/10.48440/RE3.012

[2] Weisweiler, N. L., Bertelmann, R., Cousijn, H., Elger, K., Ferguson, L. M., Goebelbecker, H.-J., Kindling, M., Kloska, G., Nguyen Thanh, B., Pampel, H., Petras, V., Schabinger, R., Schnepf, E., Semrau, A., Strecker, D., Trofimenko, M., Ulrich, R., Upmeier, A., Vierkant, P., … Witt, M. (2021). re3data Stakeholder Survey and Workshop Report. re3data. https://doi.org/10.48440/RE3.013

[3] Strecker, D., Axtmann, A., Bertelmann, R., Cousijn, H., Elger, K., Ferguson, L. M., Fichtmüller, D., Jones, C., Lindenmann, I., Neidiger, C., Nguyen, T. B., Pal, J. K., Pampel, H., Petras, V., Schnepf, E., Semrau, A., Ulrich, R., Upmeier, A., Vierkant, P., … Wright, S. J. (2023). Metadata Schema for the Description of Research Data Repositories : version 4.0. Re3data. https://doi.org/10.48440/RE3.014 p.9

Characteristics

There are different use cases and basic properties that a PID system for RDRs should have. On the basis of the PID requirements of the German National Library (cf. Schroeder, 2009). as well as the best practices for PIDs outlined by Bilder (cf. Bilder 2016), the following nine basic characteristics are defined for RDR PIDs. By embodying these characteristics, PIDs contribute significantly to the effective management, discovery, and citation of RDRs.

Uniqueness

Each identifier designates only one entity, in this case only one repository. There is no duplication, identifiers are only assigned once and are not reused. There is a unique relationship between the designated entity and the identifier.

Persistence

The identifier designates the repository for an indefinite period. If the repository changes or no longer exists, the identifier continues to exist. If only the name of the repository changes, the identifier remains the same.

Resolving

The identifier should be easily accessible and should resolve as a permanent link to the associated data or metadata on a landing page that represents the repository in the digital space. Users should be able to use the identifier to reliably locate, and straightforwardly access, the research data repository.

Interoperability

The identifier can be linked to other identifiers within its metadata. Services can be created based on these links. The identifier should be designed to work seamlessly with other identifier systems such that integration of data across different repositories is enhanced and cross-referencing facilitated.

Metadata

The identifier is associated with metadata that provides additional information about the resource. It should support linkage to comprehensive, standardized, and accurate metadata that enables understanding of the context and characteristics of the identified resource.

Discoverability

The identifier registry has an Application Programming Interface (API) that supports the discovery of metadata records.

Governance

The identifier registry has a transparent, non-profit governance structure.

Curation

The identifier registry offers organizations the ability to manage and curate their metadata records.

Scope

The identifier is not restricted to internal use and can be used and executed outside of named registries.

RDR Identifiers Indexed in re3data

The following list of identifiers is a result of requests to the re3data API to display all identifiers included in the re3data metadata schema property "repositoryIdentifier" for the 3,245 RDRs indexed in re3data as of 22 August 2024.[4] Of these RDRs, 1,246 had at least one RDR identifier (other than the re3data ID, which is assigned to all records in re3data). Some RDRs were associated with multiple identifiers, demonstrating the use of multiple systems to identify a single RDR. Several of these PIDs to identify RDRs are also used to describe research outputs in general (e.g. DOIs and RRIDs).

Curation of re3data

Information in re3data is collected through a combination of suggestions by users and manual curation by the international re3data Editorial Board.[5] Users can submit RDRs for inclusion by providing metadata, which is then reviewed for accuracy and compliance with re3data's criteria. The Editorial Board also actively seeks out and adds RDRs that meet the necessary standards for inclusion.[6] Despite these efforts, the metadata provided is not always complete or up to date, as it relies on the information submitted by users and available public sources. Therefore, a potential limitation of this study is that it reflects the data available in re3data at the time of collection, which may not always be fully comprehensive.[7]

The below table gives a summary of the identifiers and how they fulfill the characteristics described in the previous section. A more detailed description is then given of each identifier and the organization or initiative responsible for its creation/management.

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[4] The process follows notebooks published on the re3data GitHub repository. The element "repositoryIdentifier" was extracted for each repository indexed in re3data: https://github.com/re3data/using_the_re3data_API

[5] https://www.re3data.org/editorialboard, last accessed: 2024-08-26

[6] Research on RRID and FAIRsharing DOIs is actively conducted by the editors in new proposals (on RRID Portal Tools and FAIRsharing).

[7] For example, the Chinese Academy of Sciences has created Common Science and Technology Identification IDs (CSTRs) for repositories, but no CSTRs have been added to re3data yet.

	Identifier	Count	Uniqueness	Persistence	Resolving	Interoperability	Metadata	Discoverability	Governance	Curation	Scope
1.	DOI registered by re3data	3.245	✔	✔	✔	✔	✔	✔	✔	(✔)	external
4.	RRID	1.122	✔	✔	✔	✔	(✔)	✔	✔	✔	external
5.	DOI registered by FAIRsharing	776	✔	✔	✔	✔	✔	✔	✔	✔	external
6.	OmicsDI ID	182	-	-	-	-	(✔)	(✔)	-	-	internal
7.	OpenDOAR ID	89	✔	✔	✔	✔	(✔)	✔	✔	(✔)	external
8.	MIRIAM Resource (MIR) Identifier	76	✔	✔	✔	✔	(✔)	✔	✔	(✔)	external
9.	DOI	69	✔	✔	✔	✔	(✔)	✔	✔	(✔)	external
10.	ROAR ID	53	✔	✔	✔	✔	(✔)	✔	✔	(✔)	external
11.	biodbcore	52	-	-	-	✔	✔	-	✔	-	external
12.	ISSN	46	✔	✔	✔	✔	✔	✔	✔	(✔)	external
13.	ROR ID	17	✔	✔	✔	✔	(✔)	✔	✔	(✔)	external

✔ = characteristic is fulfilled

(✔) = characteristic is partially fulfilled

 - = characteristic is not fulfilled

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Digital Object Identifiers (DOIs) registered by re3data

re3data registers DOIs to uniquely identify RDRs, ensuring long-term discoverability and citation.[8] It provides a persistent link to detailed metadata, facilitating both access and cross-referencing with other identifiers. Hosted at Karlsruhe Institute of Technology, re3data is governed by a working group of experts from various partner organizations and institutions involved in Open Science, research data management, and repository services. A public API enhances discoverability, while the curation process is managed by an international editorial board to maintain accuracy. Community members can suggest updates or new records to re3data, that will be reviewed and published by the editors. Note that these DOIs are not registered for or by the repository, but are registered for the metadata record that exists on re3data.

Research Resource Identifiers (RRIDs)

RRIDs provide unique identification of research resources, ensuring persistence and clear referencing.[9] They resolve to detailed landing pages, supporting cross-referencing and data integration with other PIDs. The main governing body is the RRID Initiative, which involves SciCrunch as the primary platform for managing and issuing RRIDs (although metadata curation by resource providers is allowed). RRIDs are highly effective for uniquely identifying research resources such as biological reagents, software tools, and databases, due to their more contained and stable nature. In contrast, RRIDs may have limitations when applied to RDRs, which have broader and more dynamic characteristics and therefore require a PID system that can handle their complexity and ongoing evolution.

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[8] https://www.re3data.org/about , last accessed: 2024-08-26, see also Pampel, H., Weisweiler, N. L., Strecker, D., Witt, M., Vierkant, P., Elger, K., Bertelmann, R., Buys, M., Ferguson, L. M., Kindling, M., Kotarski, R., & Petras, V. (2023). re3data – Indexing the Global Research Data Repository Landscape Since 2012. In Scientific Data (Vol. 10, Issue 1). Springer Science and Business Media LLC. https://doi.org/10.1038/s41597-023-02462-y

[9] https://www.rrids.org and https://rrid.site, last accessed: 2024-08-26

DOIs registered by FAIRsharing

DOIs registered by FAIRSharing are used to uniquely identify standards, databases, and policies in the life sciences, ensuring consistent citation and accessibility.[10] These DOIs are assigned only once, offering persistence even if resources change. They resolve to a comprehensive landing page with rich metadata, supporting integration with other PIDs for seamless cross-referencing. Governed by a transparent and community-driven model, the FAIRsharing registry promotes interoperability. The registry also supports curation, enabling resource providers to update and manage their entries, and thus ensuring that information remains accurate over time. Again note that these DOIs are not registered for or by the repository, but are registered for the metadata record that exists on FAIRsharing.

Omicstools IDs

The identifier used in the Observational Metrics in Integrated Computational Sciences registry is called the Omicstools ID. Until 2020, the Omicstools ID identified and integrated multi-omics datasets across repositories.[11] It enabled persistent dataset-level identification, linking to metadata while supporting cross-referencing through other platforms. Omicstool ID had been developed in collaboration with several consortia and individual databases. The Omicstools ID excelled in uniquely and persistently identifying datasets and linking them across different platforms; it was not inherently designed to identify entire RDRs. In mid-2020, the Omicstools registry ceased to exit and shut down.

Directory of Open Access Repositories (OpenDOAR) IDs

OpenDOAR IDs uniquely identify open-access repositories, ensuring persistence and long-term accessibility.[12] OpenDOAR IDs resolve to a landing page with key repository

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[10] https://fairsharing.org and https://blog.omicsdi.org last accessed: 2024-08-26, see also:
Sansone, SA., McQuilton, P., Rocca-Serra, P. et al. FAIRsharing as a community approach to standards, repositories and policies. Nat Biotechnol 37, 358–367 (2019).
https://doi.org/10.1038/s41587-019-0080-8

[11] https://web.archive.org/web/20200630050608/https://omictools.com/, last accessed: 2024-08-26, https://www.omictools.com, last accessible version: 2020-06-30

[12] https://v2.sherpa.ac.uk/opendoar/, last accessed: 2024-08-29, see also: Wani, J. A., Sofi, T. A., Sofi, I. A., & Ganaie, S. A. (2023). The status of open access repositories in the field of technology: insights from OpenDOAR. In Information Discovery and Delivery (Vol. 52, Issue 2, pp. 164–174). Emerald. https://doi.org/10.1108/idd-11-2022-0119

metadata and support integration with other identifier systems. The OpenDOAR registry is governed, managed, and maintained by Jisc. Users can search, retrieve, and explore repositories through the OpenDOAR registry's API. The registry also supports curation, enabling repository administrators to update and manage their records and ensure that the information remains accurate and up to date. Although OpenDOAR is primarily aimed at open-access repositories, several research data repositories are indexed too.

MIRIAM Resource (MIR) Identifiers

Governed by the European Bioinformatics Institute, this non-profit system focuses on biological resource interoperability, ensuring high standards for dataset-level management. MIR identifiers are designed to uniquely identify and reference biological data resources within the life sciences, such as databases, datasets, and models. They are not intended to act as PIDs for entire RDRs, rather, they ensure individual resources within repositories, like datasets or models, are accurately and consistently referenced across various platforms and systems. Discoverability and accessibility are supported by the MIRIAM Registry's tools, including its resolving system utilizing the URIs of (the non-profit initiative) Identifiers.org.

(Other) DOIs

While re3data and FAIRsharing use DataCite DOIs to identify repository records on their platforms, re3data also contains additional DOIs (either from DataCite or other registration agencies) registered by organizations to assign a PID to an RDR. Each DOI is unique and remains persistent, resolving to either a landing page with comprehensive metadata about the associated resource or directly to the homepage of the RDR. DOIs are interoperable, working well with other PID systems. Depending on the registration agency, their metadata is standardized for discoverability via APIs. Although the registration agencies support standardized metadata, none of them is fully optimized to comprehensively describe an RDR.[13]

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[13] Of the 69 DOIs, 62 are from DataCite. 49 out of the 69 DOIs assigned to re3data records use the resource type "dataset" only four records use the DataCite Metadata Schema resource types "Service" or "Collection".

Registry of Open Access Repositories (ROAR) IDs

Similar to OpenDOAR, ROAR IDs uniquely identify open-access repositories, providing persistence even when repository details change.[14] The identifiers resolve to landing pages with basic metadata, supporting discoverability through ROAR's search interface and API. ROAR IDs are interoperable and integrate with other identifier systems. Governance is provided by the University of Southampton, emphasizing community-driven management, with the EPrints team maintaining and developing the registry. ROAR offers the option to leave comments and suggestions for changes to records. Though ROAR focuses on open-access repositories, some RDRs are also indexed.

BioDBcore

The BioDBcore framework standardizes the metadata descriptions of biological databases to improve findability and annotation.[15] It sets guidelines for documenting essential attributes such as scope, content, and functionality, but it does not assign or manage PIDs. The framework is externally focused, enabling broad applicability across various platforms in the life sciences. Governance is community-led through the BioDBcore working group. Because the BioDBcore framework does not maintain specific database records, there is no centralized system for curating them, and the responsibility for curating and managing records lies with the institutions implementing the framework. Primarily designed for biological databases, BioDBcore is adaptable but not specifically tailored for general RDRs.

International Standard Serial Numbers (ISSNs)

The ISSN system provides globally unique PIDs for serial publications, databases, and websites. ISSNs remain valid despite name or format changes, linking to records with metadata in the ISSN Portal. The system supports interoperability with identifiers such as DOIs. It is governed by the ISSN International Centre, which ensures transparent

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[14] https://roar.eprints.org, last accessed: 2024-08-29

[15] Gaudet, P., Bairoch, A., Field, D., Sansone, S.-A., Taylor, C., Attwood, T. K., Bateman, A., Blake, J. A., Bult, C. J., Cherry, J. M., Chisholm, R. L., Cochrane, G., Cook, C. E., Eppig, J. T., Galperin, M. Y., Gentleman, R., Goble, C. A., Gojobori, T., … Hancock, J. M. (2011). Towards BioDBcore: a community-defined information specification for biological databases. In Database (Vol. 2011, Issue 0, pp. baq027–baq027). Oxford University Press (OUP). https://doi.org/10.1093/database/baq027

and community-driven curation. ISSN records are accessible via a user interface and API, though API access is restricted to subscribers.

Research Organization Registry (ROR) IDs

ROR IDs uniquely identify research organizations globally, ensuring persistence even when organizational details change. A ROR ID resolves to a landing page with metadata about the organization and is easily linked with other open PID systems (e.g., DOIs and ORCID IDs), enhancing integration of organizational data across different systems and facilitating cross-referencing. ROR is a collaborative initiative of DataCite, Crossref, and the California Digital Library, meaning that it is open and non-profit. ROR ensures transparency and supports community-driven curation. ROR IDs are specifically designed to identify research organizations, not the repositories themselves, meaning they may not capture the full scope of characteristics of RDRs. However, ROR IDs can be linked to repositories within their metadata, indicating the organization responsible for maintaining or hosting the repository, which helps in associating the repository with its affiliated institution.

Other Identifiers

Several additional identifiers have also been indexed within re3data, albeit in smaller numbers. Identifiers with fewer than ten occurrences are grouped as "other identifiers," and include Handles, Wikidata IDs, Datenbank-Infosystem (DBIS), International Standard Name Identifier (ISNI), and Persistent Uniform Resource Locators (PURL).[16] These identifiers vary in nature, each aligning differently with the key characteristics used in the analysis, and as such, they are not included. This exclusion does not imply irrelevance; their diversity reflects their potential applicability in other contexts, meriting further exploration in future studies.

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[16] Handle 9; other 6; Wikidata 4; DBIS 2; ISIMIP Repository 1; ISNI 1; NanoMile and ERM 1; PSSB-00666 1; PURL 1

Potential Use Cases

PIDs for identifying RDRs are crucial for ensuring their accurate referencing. They enable integration into broader bibliometric frameworks and support data curation even after repositories no longer exist. The implications of such PIDs extend beyond discoverability to the long-term preservation of research data infrastructures. The following section outlines some potential use cases for PIDs for RDRs.

Aggregation

RDR PIDs help to identify and trace the aggregation of records within an RDR, which in turn enables researchers and research organizations to give credit to the RDR. Identifying RDRs through PIDs also aids national infrastructures in keeping track of the national RDR landscape. Additionally, an RDR PID enhances not only the identification of all aggregated content within an RDR but also the discovery of related resources.

Metrics

RDRs serve as containers for research outputs. An RDR PID enables accurate tracking of authorship and publication activity within a repository, and in turn improves citation and discovery metrics within bibliometric infrastructures.[17] Linking repositories to individuals, organizations, and works in information infrastructures facilitates analysis of research outputs, collaboration patterns, and citation metrics thus enhancing bibliometric insights and research evaluation. In addition, some RDR recommend that users cite the service with a PID which helps the RDR with its reputation and funding.

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[17] DataCite's repository Fabrica ID and DataCite Commons UID both uniquely identify repositories, but their scope is limited to internal systems. The Fabrica ID is resolvable through the DataCite REST API, primarily representing membership structures for repositories owned by DataCite Members. In contrast, the DataCite Commons UID provides uniqueness but is not designed for persistence. It resolves multiple identifiers such as Fabrica IDs and re3data DOIs, with metadata sourced from either re3data or DataCite clients, but also remains focused on DataCite's internal infrastructure. See also: https://support.datacite.org/docs/repository-finder#search, last accessed: 2024-08-29

Persistence

RDRs cease operation. on a fairly regular basis, often due to being tied to a project or other limited funding.[18] RDR PIDs provide a persistent reference to a repository even if it no longer exists. This ensures that repository information, such as metadata or dataset links, remains retrievable, and maintains scholarly continuity and access to research data despite institutional or operational shutdowns.

Transparency

Another potential use case for PIDs for research data repositories is ensuring transparency, integrity, and trust. PIDs can facilitate greater openness by providing a reliable way to track and verify the provenance of research outputs and repositories. By consistently linking research outputs to specific repositories and their associated metadata, PIDs allow stakeholders to validate the authenticity of the resource. This enhances trust between researchers, institutions, and the public and strengthens the integrity of scholarly communication by ensuring that the origins of research outputs are clear and verifiable over time.

Certification

RDRs are information infrastructures that seek the trust of their users as they upload valuable, sensitive, and sometimes even privacy-critical research outputs to their repositories. To ensure a trustworthy relationship, RDRs seek to meet high standards through the process of repository certification. The Core Trust Seal of Approval - a well-established certificate for RDRs - requires repositories to register their service with re3data to obtain a PID.

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[18] Strecker, D., Pampel, H., Schabinger, R., & Weisweiler, N. L. (2023). Disappearing repositories: Taking an infrastructure perspective on the long-term availability of research data. In Quantitative Science Studies (Vol. 4, Issue 4, pp. 839–856). MIT Press. https://doi.org/10.1162/qss_a_00277

Conclusion

RDR PIDs not only facilitate bibliometric tracking and interoperability but also ensure the persistence of repositories even after they are no longer active. The current landscape of PIDs that are being applied to RDRs is heterogeneous and evolving, driven by the varying needs of stakeholders to identify this important entity as part of the research lifecycle and scholarly communication. Emphasizing the importance of factors such as community engagement and long-term sustainability, this landscape overview sheds light on the diverse approaches and challenges in the realm of PIDs for RDRs. By examining the unique features, strengths, and limitations of each PID, the overview contributes to the ongoing discourse on future needs and the status quo of RDR identification. It also serves as a starting point for research to further refine the role of PIDs for RDRs; for example, extension of their scope to other types of research information infrastructures, such as open-access repositories or current research information systems.

Further Reading

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