Development and Implications of the European Open Access Research Infrastructure Project OpenAIRE (Postprint)

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Date: 2023-07-26T00:00:00+00:00

Abstract

[Objective/Significance] This study investigates the European open access research infrastructure project OpenAIRE, summarizing its successful construction experiences to provide references for the development and construction of domestic open access repositories. [Method/Process] Through literature review and web investigation, this paper examines and analyzes OpenAIRE's construction model and service functions, detailing its organizational model, data source types, interoperability guidelines, data model, data curation functions, retrieval functions, statistical functions, and multi-stakeholder-oriented service functions. [Results/Conclusion] The study concludes that OpenAIRE's content construction model oriented toward open science—which emphasizes research data openness and builds a global cooperation network platform for open access repositories—along with its service functions supporting open access policy implementation and supervision, and its top-down, unified management, division-of-labor cooperation, and collaborative co-construction management model, are worthy of reference and emulation.

Full Text

Construction and Enlightenment of the OpenAIRE Project: European Open Access Infrastructure for Research

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Abstract

[**Purpose/Significance**] This paper investigates the OpenAIRE project (Open Access Infrastructure for Research in Europe), summarizes its successful construction experiences, and provides references for the development of domestic open access repositories. [**Method/Process**] Using literature review and web-based research methods, this study examines and analyzes OpenAIRE's construction model and service functions, detailing its organizational structure, data source types, interoperability guidelines, data model, data curation functions, retrieval capabilities, statistical features, and services designed for multiple stakeholder needs. [**Result/Conclusion**] The research identifies several key success factors: an open science-oriented content construction model that emphasizes research data openness and builds a global collaborative network platform for open access repositories; service functions that support open access policy implementation and monitoring; and a top-down management approach characterized by unified administration, division of labor, and collaborative construction. These experiences offer valuable lessons for China.

Keywords: open access repository; European open access infrastructure for research; open access

1. Introduction

After nearly two decades of effort, the open access movement has achieved significant progress. Reports indicate that the global share of scholarly articles made open access upon publication has grown from 18% in 2014 to 25% in 2016 [**?**], with open scholarly resources gradually approaching the "tipping point of becoming mainstream academic resources" [**?**]. Today, openness has become a global consensus, and the movement—spanning from open papers to open data and ultimately to open science—continues to deepen with knowledge sharing as its hallmark.

Europe has consistently been at the forefront of the open access movement. In 2006, the European Research Council (ERC) issued its Open Access Statement [**?**], followed by Open Access Guidelines in 2007 [**?**]. In 2008, the European Commission (EC) launched the Open Access Pilot under the 7th Framework Programme (FP7), requiring beneficiaries in seven domains (energy, environment, health, information and communication technologies, research infrastructures, science in society, and socioeconomic sciences and humanities) to provide open access to peer-reviewed publications resulting from funded projects within 6-12 months of publication [**?**].

In this context, the EC funded the Open Access Infrastructure for Research in Europe (OpenAIRE) project in 2009 as supporting infrastructure for the pilot initiative. The project aimed to assist researchers in complying with open access policies and to help research managers and decision-makers understand project

outputs. OpenAIRE's construction comprised two components: (1) building a Europe-wide open access workforce to support localized operations, and (2) establishing an open access repository aggregation service portal for automatic harvesting and integration of content from European and global repositories, offering one-stop browsing, retrieval, access, and statistical analysis services [**?**].

China has also been actively building open access repositories. As of May 2018, the Chinese Academy of Sciences Institutional Repository Grid had stored 600,686 full-text papers, of which 313,194 were openly accessible, accumulating 18,155,990 downloads since its launch [**?**], making it one of the largest publicly-funded research output sharing systems among international research institutions. The National Natural Science Foundation of China Basic Research Repository, launched in 2015, has made 518,524 full-text papers publicly available, with 5,194,464 downloads over three years [**?**]. Despite these achievements, China's repository development has yet to involve comprehensive collection and integration of content from various types of research and educational institutions nationwide, leaving considerable room for improvement in interoperability and value-added services.

Using literature review and web-based research methods, this study investigates OpenAIRE's construction model and service functions through keyword searches in Chinese and English literature, examination of project resources from the OpenAIRE website, and hands-on use of its retrieval, browsing, and statistical features. While existing research has examined OpenAIRE from technical perspectives such as system architecture, data models, and data curation [**?**], or analyzed it as a research data repository registry system [**?**], no comprehensive analysis has synthesized its organizational model, content construction approach, and service functions. This study aims to fill that gap and provide actionable insights for domestic repository development.

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2. OpenAIRE Organizational Model

2.1 Organizational Structure

Recognizing that open access requires both global vision and local implementation, and that its advancement depends on policy, legal, management, service, and technical factors, OpenAIRE brings together IT experts, legal specialists, data scientists, and librarians from European universities, research libraries, research centers, and open scholarship organizations to achieve its objectives through collaborative construction.

To manage this diverse consortium effectively, OpenAIRE has established a hierarchical, categorized organizational structure comprising project coordinators, project managers, regional management teams, and technical management teams. Project coordinators (4 staff: 2 global coordinators, 1 scientific coordinator, and 1 technical coordinator) oversee overall coordination and management.

Project managers (5 staff: 1 project manager, 3 scientific managers, and 1 technical manager) handle organization and implementation. Regional management teams support the formation and operation of service staff teams to localize EC open access policy implementation, consisting of four regional offices (Eastern, Western, Southern, and Northern Europe) and 33 National Open Access Desks (NOADs) covering 28 EU member states plus Norway, Iceland, Croatia, Switzerland, and Turkey. Technical management teams (18 technical leads including software engineers, data engineers, and data architects) are responsible for digital infrastructure construction, operation, and maintenance of the OpenAIRE aggregation portal, as well as data integration and processing [**?**].

2.2 Management Model

Building on this organizational structure, OpenAIRE adopts a top-down, unified management approach based on division of labor and collaborative construction. The project is divided into sub-projects according to professional specialization, each led by a dedicated institution. Sub-projects are further broken down into tasks, with each task implemented by a lead institution coordinating several participating institutions. Table 1 illustrates the 10 sub-projects, their content, and lead institutions in the OpenAIRE2020 phase [**?**], demonstrating how this model leverages each partner's expertise.

Table 1 Sub-projects, Content, and Lead Institutions in OpenAIRE2020

Sub-project Content	Lead Institution
Overall coordination and management; exploring sustainable development	University of Göttingen
Promotion and publicity: developing plans, materials, channels, and events; enhancing project visibility	University of Göttingen
Open Access Repository Alliance: building alliances with global repositories to promote interoperability	University of Minho
Support and training: managing NOADs; training researchers, managers, and repository administrators; operating helpdesk	University of Minho
Open access publishing: studying workflows, methods, and costs	LIBER (Association of European Research Libraries)
OpenAIRE platform operation and maintenance: management, monitoring, deployment, upgrades, backup, and recovery	Interdisciplinary Centre for Mathematical and Computational Modelling, University of Warsaw

Sub-project Content	Lead Institution
Investigating future of scholarly communication: data privacy, impact metrics, linking publications with data, open peer review	University of Göttingen
Information space maintenance and expansion: developing data model, augmenting metadata, managing data flows, publishing linked open data	Institute of Information Science and Technology, Italian National Research Council
Knowledge extraction: developing algorithms for inference, clustering, classification, entity resolution, and scholarly network construction	Interdisciplinary Centre for Mathematical and Computational Modelling, University of Warsaw

2.3 Service Model

As supporting infrastructure for EC open access policy implementation and monitoring, OpenAIRE's service model operates through NOADs distributed across countries. These desks help researchers deposit publications and research data from funded projects into their institutional or disciplinary repositories. The OpenAIRE aggregation portal then automatically harvests and integrates metadata from these repositories, providing unified retrieval, browsing, access, and usage entry points to help researchers comply with mandatory open access requirements.

As local open access experts, NOADs engage deeply with national research institutions, communicating with researchers and managers to understand needs, promote policies, answer inquiries, and solve problems. Their responsibilities include: promoting open access concepts, policies, and best practices; addressing technical and legal issues during self-archiving; helping repository administrators understand OpenAIRE interoperability guidelines to ensure automatic metadata harvesting; assisting managers in statistical analysis of project outputs; and providing policy recommendations to decision-makers at various levels [**?**].

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3. OpenAIRE Content Construction Model

3.1 Data Source Types

OpenAIRE aims to collect three types of research outputs: (1) all globally peer-reviewed open access publications (journal articles, conference papers, theses, research reports, book chapters) preferably with project and funding information; (2) research publications funded by national funding agencies regardless of open access status; and (3) research data from funded projects or data cited

by publications in the portal [?]. To acquire this content, OpenAIRE harvests data from various sources as shown in Table 2 .

Table 2 OpenAIRE Data Source Types and Content

Data Source Type	Content Provided
Open access literature repositories	Various open access publications
Open access data repositories	Various open access research data
Research management systems	Research outputs, institutions, projects, personnel, and semantic relationships
Entity registry systems	Verified reliable information about registered projects, institutions, and personnel
Open access repository aggregation portals	Open access publications and research data

Open access literature repositories include institutional and subject repositories, such as Europe PMC [?] and the arXiv subject repository maintained by Cornell University Library [?]. Open access data repositories provide diverse research data including datasets, software applications, and audiovisual materials, exemplified by Dryad [?] and Figshare [?]. Research management systems provide not only information about outputs, institutions, projects, and personnel, but also semantic links between them. Entity registries offer verified information about projects, institutions, and personnel that can supplement and validate existing OpenAIRE metadata, such as the EC's Community Research & Development Information Service (CORDIS) [?] for FP7 and Horizon 2020 (H2020) project details; ORCID [?] for researcher profiles; OpenDOAR [?] and re3data [?] for repository metadata. Aggregation portals like LA Referencia [?], JAIRO [?], DOAJ [?], and DataCite [?] enable unified search and access across multiple repositories.

3.2 Interoperability Guidelines

To enable data exchange and automatic metadata harvesting from diverse sources, OpenAIRE has developed three sets of interoperability guidelines: *OpenAIRE Guidelines for Literature Repositories*, *OpenAIRE Guidelines for Data Repositories*, and *OpenAIRE Guidelines for CRIS Systems based on CERIF-XML* [?]. These guidelines specify recommended metadata standards and transmission protocols. For metadata, literature repositories use Dublin Core (DC), data repositories use DataCite, and research management systems use the Common European Research Information Format (CERIF). All sources must use the OAI-PMH protocol for data transmission.

To monitor open access policy compliance, output metadata must include project, funding, access rights, and embargo information. The literature

repository guidelines therefore require publications to include: (1) funder and project identifier; (2) access rights and access mode; (3) embargo period; and (4) persistent identifiers for publications and data [**?**].

3.3 Data Model

OpenAIRE's aggregation portal models not only publications and research data but also projects, funding, institutions, and data sources, creating a comprehensive information space that links research outputs with contextual information. This supports understanding the provenance of research outputs and provides the foundation for statistical analysis of funding agency outputs.

The data model must flexibly accommodate these entities and their relationships while allowing new entities and relationships to be added without disrupting existing data. OpenAIRE adopted CERIF as its underlying model, which innovatively separates base entities from linking entities. Linking entities express relationships between base entities, while a semantic layer stores and maintains terminology and enables invocation of related entities [**?**]. This approach gives CERIF the flexibility to introduce new entities, attributes, and relationships as needed.

OpenAIRE identified base entities including data source, result, person, organization, project, and funding. Linking entities such as project_{funding}, project_{result}, project_{organization}, person_{result}, organization_{result}, and organization_{funding} capture relationships between funding agencies and projects, projects and outputs, outputs and responsible individuals/institutions (Figure 1 [Figure 1: see original paper]). The semantic layer stores controlled vocabularies expressing relationships or attribute values, such as "isPartOf" to describe hierarchical relationships between funding programs, enabling statistical analysis of outputs from different program levels (Figure 2 [Figure 2: see original paper]).

Despite varying metadata formats (DC, DataCite, etc.), OpenAIRE's comprehensive entity model can accommodate all source data by mapping them to corresponding base and linking entities, establishing relationships between funding programs, funded projects, and outputs. This creates the data foundation for monitoring open access policy compliance and supports research management functions [**?**].

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4. Service Functions

4.1 Data Curation Function

As critical infrastructure supporting EC open access policy, data accuracy and completeness are paramount. Data curation involves managing data from creation to promote utilization, ensuring it remains fit for purpose and reusable

through continuous updates for dynamic data, and maintaining annotation links for published materials [**?**].

OpenAIRE uses the D-NET software platform, which provides rich data management capabilities supporting hierarchical integration of diverse source data [**?**]. The data processing workflow (Figure 3 [Figure 3: see original paper]) involves two acquisition pathways: (1) automatic metadata harvesting from validated sources, and (2) user-driven project output claiming, where users can link publications and data to projects and funding.

Raw data often contains incompleteness, duplication, and errors requiring cleaning (format conversion, supplementation, deduplication). Repository administrators must run validation tools before submission to check harvestability and metadata quality. Even validated sources require periodic revalidation due to software upgrades, metadata standard changes, or URL modifications. Data sources must be supplemented with provenance information for visibility and traceability. Duplicates from multiple sources are merged using similarity algorithms.

Cleaned data is enriched through data mining and inference techniques. Since original metadata often lacks project, funding, and access information essential for policy monitoring, OpenAIRE analyzes full texts and metadata to extract acknowledgments, identify data citations via persistent identifiers, automatically classify documents, generate subject terms, and cluster similar publications [**?**]. This enriched metadata establishes links between publications and data, and between outputs and research context, supporting advanced services. The portal also incorporates user feedback for continuous metadata improvement.

4.2 Retrieval Service Function

To meet diverse stakeholder information needs, OpenAIRE provides not only publications and data but also project, institution, and data source information. Table 3 shows the multiple search and browse pathways available for each object type, which is essential for efficient navigation of a large, multilingual, multi-source information space.

Table 3 OpenAIRE Portal Retrieval Service Functions

Object	Search Fields	Browse Paths	Page Display Content
Publication	Title, author, publisher, publication time, content type, language, data source	Funder, access mode, publication time, document type, language, funding agency, funding program, primary/secondary funding category, data source	(1) Basic attributes: title, author, type, source, subject, persistent identifier; (2) Related objects: citing publications/data, funded projects, data source
Research Data	Title, author, publisher, subject, all fields	Funder, access mode, publication time, content type, language, data source	(1) Basic attributes: name, publisher, type, description, persistent identifier; (2) Related objects: citing publications, funded projects, data source
Project	Project acronym, name, keywords, all fields	Funding agency, funding program, primary funding category, start/end time	(1) Basic attributes: name, funder, identifier, dates, responsible institution; (2) Related outputs: publications and data; (3) Statistics; (4) Tools for generating reports and publication lists
Institution	Name, acronym, all fields	Country, type	(1) Basic attributes: name, country; (2) Related objects: managed projects and data sources
Data Source	Name, English name, subject, all fields	Data source type, language, content type, OpenAIRE compatibility version	(1) Basic attributes: name, type, content, compatibility version; (2) Related objects: provided publications and data

Object pages display basic attributes and link to related objects. For example, publication pages show associated projects, while project pages show output statistics and provide tools for generating project reports and publication lists [**?**]. This interconnected presentation helps managers understand complete

project outputs and enables researchers to grasp broader research contexts.

4.3 Statistical Service Function

Based on metadata enriched with outputs, projects, funding, and access modes, OpenAIRE provides comprehensive statistics on project outputs across multiple dimensions including quantity, publication date, and access mode. Figures 4-7 [FIGURE:4-FIGURE:7] show sample statistics for FP7 and its sub-programs.

Figure 4 [Figure 4: see original paper] displays output volumes from FP7's four thematic programs and Euratom special program, with the Cooperation program generating the most publications (109,071). Figure 5 [Figure 5: see original paper] shows that nearly 70% of outputs are now open access. Figure 6 [Figure 6: see original paper] lists the top 5 FP7 projects by publication output, and Figure 7 [Figure 7: see original paper] shows annual FP7 publication volumes peaking in 2013 (46,613). These statistics help managers and decision-makers understand return on investment and policy compliance.

4.4 Multi-Stakeholder Service Functions

OpenAIRE tailors services to diverse stakeholder needs as summarized in Table 4 .

Table 4 Stakeholder Needs, Usage Recommendations, and Service Functions

Stakeholder	Needs	Usage Recommendations	Service Functions
Researchers	(1) Comply with mandatory open access policies; (2) Access scholarly resources	(1) Deposit publications and data in repositories; (2) Include project, funding, rights, embargo, and persistent identifier metadata; (3) Ensure open access	(1) Automatic metadata harvesting; (2) Unified search, browse, access, and usage

Stakeholder	Needs	Usage Recommendations	Service Functions
Project Coordinators	(1) Understand project outputs; (2) Report on project progress	Claim project publications and data	(1) Display project outputs and statistics; (2) Generate project reports
Funding Agencies	(1) Understand outputs from funded programs; (2) Monitor policy compliance	Provide project identifiers, names, dates, funding categories	(1) Browse outputs by funder/program/category; (2) Multi-dimensional statistical analysis
Repository Managers	(1) Submit repository data; (2) Increase visibility	(1) Register in OpenDOAR/re3data; (2) Self-check compliance; (3) Run validation tools	(1) Interoperability guidelines and validation; (2) Harvest metadata from validated sources; (3) Curate and enrich data; (4) Display repository information

5. Implications from OpenAIRE

OpenAIRE has significantly advanced open access in Europe, promoting policy development and digital infrastructure construction. Its aggregation portal has become a major platform for accessing global open scholarly resources and supporting policy implementation.

5.1 Open Science Content Construction Model

(1) Emphasis on research data openness. Open science upholds that all theories should withstand scrutiny and conclusions be reproducible, placing research data on par with research papers. OpenAIRE collects both outputs and contextual information from diverse sources, using data mining to enrich metadata and establish links between publications, data, and research context. This enables researchers to verify results and reuse data according to their needs, amplifying data's role in advancing science.

(2) Building a global collaborative open access repository network. OpenAIRE aims to collect global open scholarly resources by establishing a worldwide repository collaboration platform. It develops tailored interoperability guidelines for different repository types and uses the CERIF data model—an EU-recommended standard for research information systems and international standard for integrating heterogeneous data. As of May 2018, OpenAIRE had harvested from 11,675 global data sources, encompassing 23,944,971 publication records and 696,306 research data records. Table 5 shows the top 5 data sources by publication count.

Table 5 Top 5 Data Sources by Publication Count

Data Source	Records	Share
Europe PMC	[Number]	[Share]
JAIRO	[Number]	[Share]
arXiv	[Number]	[Share]
LA Referencia	[Number]	[Share]

5.2 Service Orientation Toward Open Access Policy

Sustainability is the greatest challenge facing repositories. Policy support and funding are essential guarantees. Practices show that repositories with policy and financial backing develop smoothly (e.g., Japan's JAIRO and China's CAS IR Grid), while China's university repository consortium slowed after pilot funding ended [**?**].

Closely cooperating with national and funder mandatory open access policies has proven a viable sustainability path [**?**]. Only by providing services that support policy implementation and monitoring can repositories gain sustained support. The EC invested €4.9 million in OpenAIRE (2009) to collect FP7 outputs [**?**], €5.1 million in OpenAIREplus (2011) to expand scope to research data and other funders [**?**], and €13 million in OpenAIRE2020 (2014) to support H2020's mandatory policy [**?**].

Beyond FP7 statistics, OpenAIRE now monitors compliance for numerous European funders including UK Research Council (RCUK), Swiss National Science

Foundation (SNSF), and Austrian Science Fund (FWF) [**?**]. In 2018, the Canadian Association of Research Libraries (CARL) announced collaboration with OpenAIRE to identify Canadian open access content and ensure Canada's participation in open science developments [**?**].

5.3 Top-Down, Unified, Collaborative Management Model

Repository construction models include bottom-up and top-down approaches. The former often struggles without policy support, while the latter, with decision-level backing, enables sustainable development [**?**].

As a pan-European project, OpenAIRE recognized from inception that success required multi-country, multi-sector collaboration. Partner institutions grew from 30+ in phase one to 50 in phase three, demonstrating its collaborative nature. To manage this complexity, OpenAIRE established its hierarchical organizational structure with coordinators, managers, regional teams, and technical teams. The top-down, unified management model divides work into sub-projects and tasks assigned to specialized institutions, maximizing partner strengths while ensuring coordination.

The NOAD service model, with local experts embedded in national research institutions, effectively implements EC policies at the local level. This organizational and management approach combines centralized planning with distributed flexibility, proven effective through practice.

OpenAIRE's achievements are remarkable: (1) It has driven open access development across Europe—Austria, Bulgaria, and Croatia built national repositories compliant with OpenAIRE guidelines; Luxembourg and Malta established their first institutional repositories; Poland developed a Polish DSpace version and quadrupled its repository count; multiple countries formulated open access policies aligned with EC requirements [**?**]. (2) It has built global alliances, successfully interoperating with LA Referencia and planning cooperation with China, the US, and others. (3) Through research, training, conferences, and media promotion, OpenAIRE has become a key player in European open access with global influence.

5.4 Implications for China

Few Chinese repositories currently emphasize research data openness, data management services, or link data with citing papers. Research data sharing's benefits are undeniable, and future repository development should incorporate data into collection scopes and provide data management services.

Drawing from OpenAIRE's experience, China should consider planning national-level open access infrastructure, using institutional repositories as data sources, adopting a top-down, unified management model with distributed construction and centralized presentation, designing services oriented toward institutional research management needs, and supporting national open access policies. This

could help overcome current challenges in university repository development [?] and advance China's open science agenda.

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Construction and Enlightenment of the OpenAIRE Project of the Open Access Infrastructure for Research in Europe

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Abstract: [Purpose/significance] This paper carries on research on the OpenAIRE project of open access infrastructure for research in Europe, analyzes its successful experiences, in hope of providing references to domestic open access repositories. [Method/process] Based on the methods of literature study and internet survey, this paper investigated and analyzed the construction model and service function of OpenAIRE from organization model, type of data sources, interoperability guidelines, data curation, information retrieval function, statistics function and functions for multiple stakeholders. [Result/conclusion] The research summarizes its successful experiences, including the open science content construction model which emphasizes the research data management and building a global collaborative open access repositories, the service functions which support open access policy and the management mode whose characteristic is from top to down, unified management, cooperation and coordination.

Keywords: open access repository; OpenAIRE; open access

Note: Figure translations are in progress. See original paper for figures.