FID Civil Engineering, Architecture and Urbanism digital - A platform for science (BAUdigital)

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Abstract

University Library Braunschweig (UB Braunschweig), University and State Library Darmstadt (ULB Darmstadt), TIB – Leibniz Information Centre for Technology and Natural Sciences and the Fraunhofer Information Centre for Planning and Building (Fraunhofer IRB) are jointly establishing a specialised information service (FID, "Fachinformationsdienst") for the disciplines of civil engineering, architecture and urbanism. The FID BAUdigital, which is funded by the German Research Foundation (DFG, "Deutsche Forschungsgemeinschaft"), will provide researchers working on digital design, planning and production methods in construction engineering with a joint information, networking and data exchange platform and support them with innovative services for documentation, archiving and publication in their data-based research.

Keywords

Architecture, Building and Construction History, Construction Research, Sustainable Building Technology, Structural Engineering, Building Informatics and Construction Operation, Urbanism, Spatial Planning, Transportation and Infrastructure Planning, Landscape Planning, Specialised Information Service, Research Data Management, Research Information, Research Infrastructure, Digital Library

Current developments, digital methods and technologies in civil engineering, architecture and urbanism

Digitalisation has long since reached the building industry: new digital design, planning and production methods enable more efficient and sustainable construction. Intensive research is currently being carried out at numerous universities. *Computational Design, Computer Aided Manufacturing, Additive Manufacturing, Adaptive Building Envelopes, Building Information Modelling, City Information Modelling* and *Sustainable Urbanism* are terms that are often mentioned in this context.*[1]

There is a high degree of interdisciplinarity and networking in the predominantly young specialist community. Research results from other disciplines such as mechanical engineering, computer science or the social sciences are successfully transferred to construction engineering. At the same time, the formerly clear boundaries between the sub-disciplines of construction engineering are beginning to dissolve more and more and collaborative working as well as research methods are becoming established.

With the major research projects currently approved by the DFG, such as the Cluster of Excellence IntCDC*[2], the Collaborative Research Centres (SFB) Adaptive Envelopes and Structures for Tomorrow's Built Environment (SFB 1244), Additive Manufacturing in Construction (AMC) and the Digital Building Fabrication Laboratory (DBFL), as well as the priority programme "Hundert plus" (Hundred plus), the success of these innovative and experimental research approaches is clearly evident. Beyond these exemplary DFG projects, numerous other research projects have been carried out in recent years to develop digital design, planning and construction methods, new professorships have been established and new conferences and associations initiated.*[3] From the political and legislative side, this development is flanked by a whole series of funding initiatives and position papers. For example, the Bundesministerium für Digitales und Verkehr (Federal Ministry for Digital and Transport) published the "Stufenplan digitales Planen und Bauen" (Step-by-Step Plan for Digital Planning and Construction) in 2015*[4], and in 2016 the Bundesministerium des Innern, für Bau und Heimat (Federal Ministry of the Interior, for Building and the Home Affairs) launched the National Dialogue Platform Smart City.*[5]

The joint use of the many data produced in the construction industry and in construction-related research opens up entirely new approaches to planning and thinking. Numerical building simulations already provide answers to a wide variety of complex questions - both with regard to new buildings and the existing building stock. Researchers also expect to gain fundamental insights from the networking of extensive data sets collected by urban institutions (public administration), knowledge institutions (universities, Federal Institute for Research on Building, Urban Affairs and Spatial Development), by large technology and industrial groups and increasingly by citizens themselves (citizen

science). The terms *digital city* or *smart city* stand for concepts of a holistically oriented sustainable city.*[6]

The digital transformation is also changing scientific reflection on buildings and planning of the past. For example, digital methods and tools such as laser scanning, structure from motion and LiDAR (Light Detection and Ranging) have long been established in historical building research and building archaeology, which helps not only to document and research the building cultural heritage, but also to reconstruct lost building contexts (digital reconstruction). In addition, the large architecture collections such as the [Deutsches Architekturmuseum Frankfurt](#) (DAM) and the [Südwestdeutsches Archiv für Architektur und Ingenieurbau](#) (saai) are currently intensively dealing with the transformation into the digital: What workflows and process chains are required to make the heterogeneous digital source material from architects' and office estates — which is predominantly available in "historical" file, programme and media formats — productive for research? What digitisation strategies are required to transfer difficult-to-access objects such as sensitive architectural models into the research process as 3D digital copies?

Several surveys, a workshop and interviews with researchers from the steadily growing research community demonstrate the urgent need for a joint information, networking, research and data exchange platform for the disciplines of civil engineering, architecture and urbanism. To meet this need, the specialised information service (FID) BAUdigital was launched in 2020. The public kickoff event of the FID on March 2nd 2021 was attended by around 200 participants from the respective communities, which underlines the great interest in joint networking.

Goals and work programme

Within the first DFG funding phase (2020–2022), the focus is on developing and establishing the FID BAUdigital as a central contact point and customised service offering for the disciplines of civil engineering, architecture and urbanism (spatial planning).*[8]

For this purpose, a web service platform is being developed which offers media and information with a focus on digital methods and technologies in construction engineering. It provides fast, highly up-to-date and location-independent access and re-use options to research information and data in accordance with the FAIR principles.*[9] The establishment of an innovative and communitynetworking repository for 2D and 3D research data and the use of specific tools for textual and visual searches will facilitate the search for relevant information. This will primarily create informational services in the field of construction engineering and provide reusable tools to support the entire [research data life cycle](#). In order to address the identified areas of need, eight fields of action (AF, "Aktionsfelder") are envisaged in the FID:

- AF 1: Communication and interaction with subject communities
- AF 2: Web service platform and research
- AF 3: Subject Thesaurus

- AF 4: Retro-digitisation, retro-digitisation service
- AF 5: Research data management and curation
- AF 6: Long-term archiving
- AF 7: Research and infrastructure networking
- AF 8: Open Access and publication services

The project will be implemented in four phases, the contents of which are summarised in Fig. 1.

Through their previous activities, the institutions involved in the project have extensive expertise for the successful implementation of the planned AF. In order to ensure the most efficient cooperation possible and at the same time make use of existing synergies, content-related focal points are defined for each project partner and close exchange in the individual AF is agreed. The eight fields of action of the FID BAUdigital are in detail:

Field of action 1: Communication and interaction with the scientific communities

The project partners jointly establish continuous communication with the expert communities, which accompanies and supports the entire project duration. This involves carrying out needs analyses for the various FID offerings and regularly informing the scientific communities about the project developments as part of the public relations work of the FID BAUdigital. For the development of a sustainable research data repository (cf. AF 5 and AF 6), a targeted needs analysis that was already started when the FID project application was submitted will be continued and expanded, taking into account research-relevant data, simulations and digital research software from the addressed areas. An important instrument for this is the identification of so-called use cases, which represent the research practice of the FID community in a sub-disciplinary and method-specific manner.

For this, experts from the most important research institutions (1st phase: TU Braunschweig, TU Berlin, University of Stuttgart, Bauhaus University Weimar) will first be involved in preparatory, then in-depth discussions and finally focus group workshops. In addition to the relevant aspects of the research data life cycle, the processes associated with data analysis and re-use as well as the research software used also need to be surveyed. For this purpose, 3D sample data from all areas of the cluster have already been compiled in advance. In parallel, the significance of existing portals and initiatives*[7] as well as the latest infrastructural developments (e.g. through the National BIM Competence Centre, through the relevant National Research Data Infrastructures (NFDI)) will be evaluated in feedback with the scientific community.

In addition to the collection of use cases, the needs analysis takes the form of an online survey on the topic of "Open Access and Research Data". The results form the basis for the FID's publication services and Open Access information offerings (cf. AF 8), but also provide information for research data management (RDM), long-term archiving and the development of the subject thesaurus (cf. AF 5, 6 and 3). Various preliminary work on the

project (initiative online survey, workshop, research) revealed that the publication cultures of the disciplines involved differ, so that an in-depth analysis of the subject specifics seemed necessary. This was implemented through the online survey on concrete, subject-specific desiderata and through in-depth focus group workshops. The online survey started in March 2021 with a duration of two months. A summary of the evaluation will be published shortly.

To continuously ensure an effective user feedback and the quality of the FID services developed, a scientific advisory board has been established. Eleven scientists representing the various subject areas actively accompany the FID's community-oriented development from a scientific point of view and provide support through regular advisory board meetings, participation in workshops and consultative discussions.

The FID BAUdigital as a new specialised information service, its related content, research tools and research-supporting services must be communicated to the community in order to reach a steadily growing user base. This task is taken on by intensive public relations work in the scientific (e.g. institutions and associations in the construction industry) and social (e.g. Twitter) communication channels. This includes regular contributions in the form of postings, blogs, articles or newsletters as well as active participation in selected events. The FID BAUdigital was very successful in introducing itself to the professional communities with a digital kick-off event on March 2nd 2021 with around 200 participants. Further event formats are planned.

Field of Action 2: Web service platform and research

Based on the formulated needs of the community, AF 2 is developing a web service platform that encompasses all FID value-added services, makes all relevant information available and will be a central point of contact. The development of the web service platform is taking place in an agile process and in exchange and feedback with the community.

In addition to searching in diverse information resources, an efficient method of indexing and searching in different types of research data including metadata, image, 3D data and AV data will be offered.

The focus is on fast, up-to-date and location-independent access to information and media offerings as well as the subsequent use of research results and data in the sense of the FAIR principles.

The basis of the literature and information supply is formed by the extensive subject-related holdings of UB Braunschweig, ULB Darmstadt, TIB and Fraunhofer IRB. The content strategy of the FID BAUdigital is continuously refined and the content is optimised in exchange with the scientific community as well as in coordination with related FIDs and other infrastructure institutions. In addition to the literature supply in Open Access, the TIB's document delivery service will be available to users, offering rapid provision of

documents in electronic or printed form or direct access to electronic full texts and multimedia objects.

The web service platform will include the following service components:

- Search in subject-relevant information resources
- Integration of subject-relevant AV media from the TIB AV-Portal
- Integration of the TIB's document delivery service
- Subject-specific BAUdigital Thesaurus as Linked Open Data (LOD)
- 3D retro-digitisation service
- Research data management and long-term archiving of research data through a digital repository
- Networking and interaction within the community through a BAUdigital research atlas
- Information and advisory services on Open Access

Field of action 3: Subject-specific thesaurus

One of the central concerns of the FID BAUdigital is to support researchers in their search for relevant literature, research data, projects and partners. Controlled vocabularies such as subject-specific thesauri are an important tool, usually invisible to the user, for finding the information they are looking for quickly and accurately. Semantic knowledge organisation systems enable explorative access to widely distributed resources and form communication bridges between different disciplines as well as between technical and general language. In this way, they are a suitable instrument for optimising the processes of information acquisition in the context of interdisciplinary fields such as constructional engineering. AF 3 is investigating the possibilities of thesaurus-based access for interdisciplinary searches via the BAUdigital web service platform (cf. AF 2) and in the BAUdigital research data repository (cf. AF 5) and is providing one of the building blocks for the functionality of the research atlas (cf. AF 7).

For this purpose, existing subject vocabularies are to be re-used within the framework of the project, adapted if necessary and implemented. An important starting point is formed by two comprehensive indexing systems (*FINDEX Bau* in Fraunhofer-Informationszentrum Raum und Bau IRB (1985a), Fraunhofer-Informationszentrum Raum und Bau IRB (1985b) and *FINDEX Raum* in Fraunhofer-Informationszentrum Raum und Bau IRB (1993)), hierarchically divided into four levels. They were developed and agreed on in the 1980s by, among others, the DIN Standards Committee Building and Civil Engineering (NABau), the International Council for Research and Innovation in Building and Construction (CIB) and the Federal Research Institute for Regional Geography and Spatial Research ("Bundesforschungsanstalt für Landeskunde und Raumordnung (BfLR)" until 1998) at the Fraunhofer IRB. The basis for subject indexing at the Fraunhofer IRB is an additional IRB subject vocabulary, which is continuously being expanded and contains approximately 30,000 additional German-language subject keywords in unstructured form. In order to integrate the keyword catalogue and the structured and thus more expressive FINDEX thesauri and to be able to transfer them into a new,

multimodular BAUdigital thesaurus, content-related, structural and technical adjustments are necessary.*[13]

So far, the two subject thesauri FINDEX Bau and FINDEX Raum have been technically revised to publish them on a public GitLab repository. *[10] In the spirit of open science and FAIR-compliant data management they are now available for re-use by FID BAUdigital and also other interested parties. Both thesauri were published in the context of the project under a Creative Commons NC-SA 4.0 licence as SKOS*[11] resources in various standard formats (ttl, rdf/xml). The SKOS versions of the two thesauri*[12] attempt to map the original structure of the print templates as accurately as possible using hierarchical and associative relations and defining synonyms. To structure the terms of the keyword catalogue, a new subject classification was developed — partly with the involvement of the community — which generally provides for two levels and an additional third level for the subject area of digital planning and building.

In the further course of the project, an integration of the mentioned sources into the BAUdigital Thesaurus as well as its expansion via the mapping of further subject-relevant sources are planned. In addition, newer concepts from the current research landscape should also be able to be suggested by the community: For this purpose, the thesaurus will be created as an open resource to which suggestions can be contributed according to defined editorial procedures.

Field of action 4: Retro-digitisation of 2D and 3D objects, development of a 3D retro-digitisation service.

Among the offerings of the FID BAUdigital will be a retro-digitization service for the community. The 3D scanning arm (CultArm3D-P) developed by the Fraunhofer-Institut für Graphische Datenverarbeitung IGD (Fraunhofer Institute for Computer Graphics Research) will be used to digitise architectural models. Using a method developed by Fraunhofer IGD for autonomous view planning, the scanner is able to independently capture any object geometry with the smallest number of images with optimal overlap and at the correct focal distance from the object surface. The system thereby enables 3D models that are not only true to scale, but also true to colour of the real architectural models.

By automating the 3D digitisation process, it is possible to achieve results of repeatable high quality as well as an increase in throughput while at the same time making the scanning system extremely easy to operate. The view planning procedure significantly reduces the number of unrecorded undercuts and faults in the 3D models, so that post-processing of the models is no longer necessary in some cases and a complete 3D model is available immediately after 3D reconstruction. Downstream process tools developed by Fraunhofer IGD allow automatic reduction of large 3D model data (*.obj formats) for a wide range of applications up to their interactive presentation via the web (*.glTF, *.glb formats) in virtual or augmented reality.

Within the first funding phase, about 150 models will be digitised, enriched with metadata and integrated into the BAUdigital research data repository. For this purpose, a service concept for the mobile CultArm3D is being developed to support research archives and architecture museums in digitising their models on site.

With the retro-digitisation and creation of machine-readability of already published image resources — especially of plans (floor plans, sections, views), but also of source material from architectural archives — valuable research data will be made available to the addressed disciplines. The initial plan is to digitise already published floor plans, which will be integrated into a plan repository. This is based on a self-learning intelligent image and geometry recognition (metadata enrichment, structure development and clustering) and will be successively trained on search scenarios for civil engineering, architecture and urban studies through the retro-digitised source material. The focus will be on geometry-based information such as construction and dimensioning, building and housing typologies, specific spatial configurations (including style recognition) and networking with geocoded data.

The aim is to establish interlocking and compatible workflows in the research data life cycle: from the creation and processing of research data, to standardisation in open formats capable of long-term archiving, to curation (enrichment with metadata) as well as publication and re-use of the research data. The last three process steps in particular require both library and discipline-specific expertise, as well as information science and information technology know-how. In order to achieve retrievability and optimal re-use of research data, it is necessary to define (re-usable and further developable) standards for the ingest of data into the research data repository.

Field of action 5: Research data management and curation

A key task of the FID BAUdigital is the development of a research data repository. Networking, integration and exchange of research data across organisational, subject or regional boundaries are core tasks for information infrastructures in the digital age and a source of new scientific knowledge. Two types of data can potentially be distinguished for the FID in terms of their structure and reusability:

- *Digital Born Data*: This type of data usually accumulates in the planning and analysis stage within the research data lifecycle and is characterised by a frequently software-related strong heterogeneity within the disciplines and a lack of standardisation of metadata. Examples are process and modelling data in formats such as CIM, BIM, CAD and LiDAR.
- *Retro-digitised 2D and 3D objects*: This data type includes previously published research data and documents that are the result of a previous research data life cycle. In accordance with the FAIR principles, they can become the subject of a new research data life cycle by establishing machine-readability and digital interpretability.

The scientifically adequate handling of such data requires structured research data management (RDM), ideally maintained by all parties involved in the research data life cycle. For the storage, curation and publication of these research data, the FID will set up a BAUdigital research data repository tailored to its scientific communities. This will ensure the permanent retrievability and re-usability of research data in accordance with the FAIR principles and increase the reproducibility and transparency of research results.

The repository will be based on the open data management system CKAN, with which different metadata schemas (e.g. DataCite) and specialist vocabularies (cf. AF 3) can be integrated via plug-ins. In addition, suitable RDM workflows can be designed analogous to the existing research processes in the community. The use cases developed with the community and the test data sets provided will serve as the basis for this. The technical expansion of the repository is accompanied byevents and training for the community.

The repository is also integrated into the national and international information infrastructure. Existing RDM systems and storage infrastructures will be re-used. Its design of a publicly accessible application programming interface (API) is intended to make the integration of services (from project partners and also third parties) as easy to use and flexible as possible. The primary focus is on the connection to the RDM systems of the ULB, to the research information system VIVO (incl. Research Atlas, cf. AF 7), to the DOI service of the TIB, to a workbench (see below) and to the long-term archiving systems (cf. AF 6).

With the help of a workbench, researchers will be able to upload and visualise their research data before publication. In addition, the workbench supports the creation of standardised data packages (homogenisation) and semiautomatic semantic enrichment with metadata for future publication in the repository. At the same time, routines are developed for converting the data formats for subsequent use of the data in accordance with the FAIR principles and for long-term archiving (cf. AF 6).

The research data deposited in the repository will be linkable with data from other research data resources. This requires appropriate metadata for rapid retrieval and re-use, but also for their machine processing. 3D data in particular are still characterised by proprietary data formats and their standardisation has not yet been completed. To remedy this, the FID will develop lossless transformation methods for typical cases. Recommendations for uniformity in data description and structuring are also being developed together with the community.*[14] In addition, DataCite is "used" as a metadata format via DOI referencing, so that, for example, automated verification in other information portals on research data is possible. Finally, the FID will use schema.org as a vocabulary for the purpose of improved findability, e.g. via search engines.

Researchers can store relevant metadata and data directly in the research data repository and continue working on them there (including versioning). However, they can also work on other repositories such as Zenodo or a local filing system and then report the data to the FID. The FID web service platform will harvest these distributed research data or digital collections and integrate them according to the developed standards (Lin

et al. 2020). Institutions that want to support the FID's offer can thus support their community on the basis of ResourceSync*[15] in particular and keep diverse resources in sync in a distributed scenario. Finally, common technical standards are to be offered for external queries of metadata.*[16]

Field of action 6: Long-term archiving

While repositories for research data are oriented towards current usage scenarios and archiving here only means five to ten years, digital long-term archiving also focuses on future questions of usage. The FID BAUdigital wants to think about the processes of certified long-term archives from the first delivery of research data to the FID infrastructure. The aim is the long-term archiving of objects in the digital archives of TIB and TU Darmstadt.

Producers and users of scientific materials place high demands on the information they use in terms of integrity, authenticity, durability and citability. From the perspective of a sustainable FID, not only today's but also future usage scenarios must be taken into account. The TIB operates one of the few CoreTrustSeal and nestor seal DIN 31644 certified digital archives in Germany. At the same time, other digital archives are being tested and set up, including at the ULB Darmstadt.

The Open Archival Information System (OAIS) reference model (ISO 14721, cf. OAIS 2012) defines an Open Archival Information System as a system that is composed of technology and human resources and has assumed responsibility for the long-term preservation of digital objects for a defined target group (designated community). The processes to be established and thus all decisions for archiving measures must be tailored to this target group. The mentioned survey on "Open Access and Research Data" (cf. AF 1) identified some of the initial needs with regard to formats and content used.

A FID BAUdigital information package to be archived is to be understood as the connection of a digital object delivered by data producers with all metadata and representations created in further FID BAUdigital processes (cf. AF 5). The following package structures based on the OAIS exist for the information package:

- *FID BAUdigital Submission Information Package* (SIP): In addition to the digital object itself, the FID BAUdigital SIP contains all the information needed to further preserve the integrity, authenticity and long-term availability of the digital object. This includes, for example, integrity information in the form of checksums, but also information on the usage and archiving rights of the digital object. This SIP is specified generically enough to enable a deposit in different long-term archives such as the Rosetta-based Digital Archive of the TIB and the Archivematica-based archive of the ULB Darmstadt.
- *FID BAUdigital Archival Information Package* (AIP): As part of the inclusion of a SIP in a digital archive, further essential information is collected for the long-term archiving process. In particular, processes must exist that can handle the respective file formats. At the end of this recording process is the AIP, on the basis

of which all measures for long-term preservation can be planned, carried out and checked. Preservation measures must be in line with the intended use scenarios of the defined target group — for example, should a CAD plan only be read or does the future use scenario also include further processing of the CAD plan itself? Two AIP variants exist within the framework of FID BAUdigital: That of the digital archive of the TIB and that of the digital archive of the ULB Darmstadt. Mapping the AIP to the FID BAUdigital SIPs (transformation documentation) ensures an AIP-to-AIP transfer of the two archive systems.

- *FID BAUdigital Dissemination Information Package* (DIP): Usage packages are delivered from the respective archives as DIPs. Here, the content of the DIP is to be adapted to the respective usage scenario. Since this FID BAUdigital information package contains all the information collected in various processes, it is also possible to (re)supply the platforms and the users behind them.

Field of action 7: Research and infrastructure networking

The task of AF 7 is to develop a research and infrastructure map ("research atlas" BAUdigital) for the scholarly community of actors in digital planning and building. The research atlas is intended to serve as an aggregator for existing information on research activities and output of scientists on the one hand and infrastructure and service offerings on the other. The Linked Data-based open source software VIVO (Conlon et al. 2019) is used for this purpose, which is also the case for the FID move's research compass (Wolff et al. 2021).

The base of the research atlas are semantically enriched profiles with individual bibliographies of researchers. Researchers are authenticated via ORCID integration. Publications can be imported via a DOI import, but also directly from the ORCID profile. The researchers retain profile sovereignty, e.g. they themselves can decide which publications are used to present their research field-specific expertise in their own profile. This builds on developments from the OpenVIVO project (Ilik et al. 2018).

An essential component of the future research atlas is a map of research objects. These can be, for example, building projects, publications or actors and their institutions. Using spatio-temporal metadata, a map based on open data and technologies will visualise where research facilities are located. Spatio-temporal metadata of research datasets (or their analogue twin) should also be used and visualised in the map. The map will offer functionalities to serve as an entry point into the research for building objects. For this purpose, different discovery layers will be built into the map to enable searching and filtering of information within the map. The objects shown on the map are linked to profiles of related persons, organisations, projects, events, etc.

In order to serve as an discovery entry for subject-specific information and actors, the integration of the subject-specific thesauri developed in AF 3 and the corresponding infrastructure is planned. This includes the integration of a lookup service that researchers can use to label their research fields by means of controlled vocabularies; furthermore, the expansion of the functions provided by VIVO for the representation of

keywords and their interlinking with various entities is planned. For the keywords used in the research atlas, a profile page will be developed to support the identification of relevant research outputs and the actors behind them and resulting networking activities. Publications, projects, organisations and persons associated with this concept will be displayed in these profiles. Visualisations integrated into the topic pages will also enable exploration of the content of the research atlas.

Finally, the research atlas will be connected to the web service platform. For this purpose, it will be systematically gathered which data those systems offer and in which form these data are described in each case (metadata schemata).

Field of action 8: Open Access and publication services

The FID BAUdigital will develop information and advisory services on Open Access (OA) publishing specifically for the scientific communities of (digital) construction engineering.

Up to now, a lack of knowledge or insufficient support services has often led to researchers in FID-relevant disciplines refraining from OA publishing. This was confirmed by the preliminary work of the project as well as by the online survey conducted by the FID on the topic of "Open Access and Research Data Management" (cf. AF 1). The most frequently cited reasons why researchers in the FID community do not publish in OA include the perceived lack of reputable journals/publishers, a perceived lack of reputation of OA publications in general, and the lack of information and support services. Researchers are also often unaware of the implementation of the right of secondary publication ("Zweitveröffentlichungsrecht", self-archiving) or rarely use it due to legal uncertainties. Overall, the results of the survey lead to the conclusion that there is an urgent need for community-specific information, advice and training services in the field of OA. In fact, there is currently no centrally bundled information on reputable OA journals for the communities involved in BAUdigital, and the corresponding search for high-impact journals is a time-consuming hurdle for researchers. Based on the results of the FID's online survey and the findings from two focus group workshops on "Publishing and Open Access in Construction Engineering and Architecture", which were conducted with representatives of the community, the concrete needs of researchers will be identified and transferred into a portfolio of topics for information, advice and training services for OA publications. The FID will offer community-specific information and advice on the following topics:

- General information on OA and free licences
- Funding opportunities for first publications
- Identifying high-quality, subject-specific OA journals
- Information on predatory publishing
- Using the right of self-archiving ("Zweitveröffentlichungsrecht")

With the information and counselling offers, the aim is to promote awareness among academics for a higher acceptance and an increased OA output. Therefore, subject-

specific workshops and online courses will be designed, which will impart relevant knowledge on OA.

In order to increase the proportion of self-archiving publications, a support for checking self archiving opportunities will be designed. In addition, there will be trainings held for researchers how to check the possibility for self-archiving for themselves.*[17]

Cooperation and regular exchange with other research funding programmes and information institutions will accompany the work of AF 8, specifically with the OA coordinators of TU9, the corresponding task areas of NFDI4Ing and NFDI4Culture, the OA contact persons of other FIDs, the information portal open-access.network and other OA-related projects such as B!SON and ConfIDent.

AF 8 will also be responsible for identifying the need for OA transformation contracts for currently subscription-based journals. For this purpose, the FID will identify the journals that are most attractive for its communities and in which researchers publish most frequently, in order to derive transformation strategies for a later date. Another goal is to identify publication opportunities for conference papers, which, according to the results of the above-mentioned needs evaluations, represent a significant publication output of the FID community. It is also worth exploring whether there is a need to establish a subject-specific overlay journal during a further funding phase.

Summary and outlook

The FID BAUdigital supports scientists in their data-based research and the publication and visualisation of research results via a long-term web service platform with connected services. The hitherto untapped potential of research data has also been recognised in science policy and, for example, was set out in the coalition agreement of the Federal Government in 2021 (SPD et al. 2021).

With the FID's research data repository, researchers in the addressed disciplines are actively supported in the systematisation, documentation and long-term provision of their research data in various formats and software versions. In addition, the FID will create the possibility of long-term archiving of research data for the addressed community and a research atlas for networking researchers, research results and data.

A retro-digitisation service will be set up to support research archives and architecture museums in the digitisation of 3D models. Retro-digitised 2D and 3D objects will be transferred into the FID's own research data repository and made accessible as research data.

Subject-specific and research-relevant information and media are made accessible and searchable via the web service platform. The document delivery service and the TIB AV-Portal complement Open Access offerings. Information, advice, assistance and training on publication options for OA publications complete the services offered by the FID.

Fig. 2 illustrates the planned system architecture of the FID, including the planned data flows and cooperation between the fields of action.

Through further networking and consolidation of the FID BAUdigital and its services within the specialist communities, the services will be evolved and supplemented as needed. This includes further integration with the NFDI, such as NFDI4Culture and NFDI4Ing, both in terms of communication and joint events as well as in terms of tool development. The intended goal must be to create a modular research data infrastructure that is assembled from services of all projects. Nevertheless, we are aware that we have to differentiate: 4Culture contains mainly the community dealing with historical architecture, 4Ing has the whole range of construction and engineering. Even if the (research) datasets are technically similar, the workflows are completely different, which in turn has an impact on the services. Furthermore, interdisciplinary exchange is to be expanded with related specialised information services such as [FID move](#) and [arthistoricum.](#)

The first joint collaborations and topics have already been initiated, including possibilities for providing evidence of research data from the NFDI on the FIDs' web service platforms, coordinated outreach to specialist societies and joint communication to the communities.*[18] Regular Data Talks and further workshops on specific individual topics, partly in cooperation with other FIDs, NFDIs and other projects and initiatives*[19], are in preparation (e.g. on retro-digitisation, BIM data, metadata standards, questions of re-use rights of digital data, Open Access in the engineering sciences). The discussions and feedback during the various presentations of the FID BAUdigital so far showed that the services already started are perceived positively and usefully in the addressed specialist communities.

As mentioned above, the FID BAUdigital will contribute to an overarching overall structure of specialised information services and participate in the discussion about a long-term continuation of these services. We plan to submit an application for another funding phase, in order to further expand the services and strengthen interdisciplinary networking between the disciplinary cultures. In exchange with the community, universities and non-university research institutions, professional societies, related FIDs and NFDIs as well as other research-related service providers, the FID BAUdigital aims to establish itself as a long-term, location-independent service platform for researchers in civil engineering, architecture and urbanism.

Funding program

Grant title

FID Bauingenieurwesen, Architektur und Urbanistik digital (BAUdigital) - Project number 432774435

Conflicts of interest

The authors declare that there are no conflicts of interest.

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Endnotes

[*1] Examples: "Institute for Computer-aided Design and Construction" University of Stuttgart (https://www.icd.uni-stuttgart.de, 10.12.2021), "Chair for Computer-aided Design" ETH Zurich (https://www.caad.arch.ethz.ch/, 10.12.2021), "BIMLab@HCU" HCU Hamburg (https://www.hcu-hamburg.de/research/bimlab/, 10.12. 2021), "KityVR" TU Graz (https://graz.pure.elsevier.com/de/projects/kityvr-artificial-intelligence-for-the-generation-of-citygml-mode, 10.12.2021), "Institute for Sustainable Urbanism" TU Braunschweig (http://sustainableurbanism.de/, 10.12.2021), "Smart Design and Construction (SDaC)"(https://sdac.tech, 10.12.2021).

[*2] "Integrative computer-based design and construction for architecture"

[*3] Example of such an association (since the end of 2020): "AdvanceAEC - Research Network for Advancing Architecture, Engineering and Construction".

[*4] The 2015 Step-by-Step Plan for Digital Design and Construction and other, more recent position papers and progress reports are available at: https://www.bmvi.de/SharedDocs/DE/Artikel/DG/digitales-bauen.html (13.01.2022).

[*5] In 2017, the Smart City Charter was presented. Since 2019, the BMI has been funding numerous Smart City model projects with around 820 million euros (https://www.bmi.bund.de/DE/bauen-wohnen/stadt-wohnen/stadtentwicklung/smart-cities/smart-cities-node.html, 13.01.2022).

[*6] See, for example, within the framework of the research focus "City of the Future" at the TU Braunschweig (https://www.tu-braunschweig.de/forschung/forschungsprofil/schwerpunkte#c515019, 13.01.2022).

[*7] E.g. re3data.org, search.datacite.org, https://www.idc.ch/archicad/bimcloud/ueber-bimcloud/, http://openbim.ch as well as general re-use of data from long-term archives of the project sites.

[*8] The FID BAUdigital is primarily aimed at researchers from the following three DFG subject groups: No. 410-01: Architecture, History of Building and Construction, Construction Research, Resource Economics in Construction, No. 410-02: Urban

Planning/City Development, Spatial Planning, Transport and Infrastructure Planning, Landscape Planning and No. 410-04: Structural Engineering, Construction Informatics and Construction Operations (https://www.dfg.de/dfg_profil/gremien/fachkollegien/faecher/, 22.12.2021).

[*9]   Cf. Wilkinson et al. (2016). More detailed explanations at https://www.go-fair.org/fair-principles/.

[*10] Terminology repository of the FID BAUdigital on GitLab.com: https://gitlab.com/fid-bau/terminologie.

[*11] SKOS Simple Knowledge Organization System Primer (2009), http://www.w3.org/TR/skos-primer.

[*12] FINDEX thesauri in SKOS format, https://irb.fraunhofer.de/findex-thesauri.

[*13] Subject classification in SKOS format, https://gitlab.com/fid-bau/terminologie/fid-baudigital-faecherklassifikation.

[*14] Particular emphasis is placed on the one hand on the integration of standards data for entities such as persons, corporate bodies, places, time and form terms, and on the other hand on a consistent description at the collection level, depending on the respective functional areas and common standards. For the latter, the Dublin Core Collection Description Application Profile (https://www.dublincore.org/specifications/dublin-core/collection-description/collection-application-profile/) recommended by the DFG Practical Guidelines and the DCAT format recommended by the W3C (https://www.w3.org/TR/vocab-dcat-2/) serve as a basis, cf. DFG (2016).

[*15] ResourceSync builds on the sitemap protocol and is equally suitable for data, metadata and LOD (http://www.openarchives.org/rs/toc, 22.12.2021).

[*16] This is done via a SPARQL endpoint of the repository or a comparable REST-based technology such as OpenAPI/Swagger (https://swagger.io/specification/, 22.12.2021).

[*17] For example, it is being examined whether tools that have already been developed in other projects such as DeepGreen or Dissemin to increase the proportion of second publications can be re-used and adapted.

[*18] Corresponding topics were discussed, among others, on 8 November 2021 in the "DFG Round Table: FID and NFDI", organised by the FID Steering Committee.
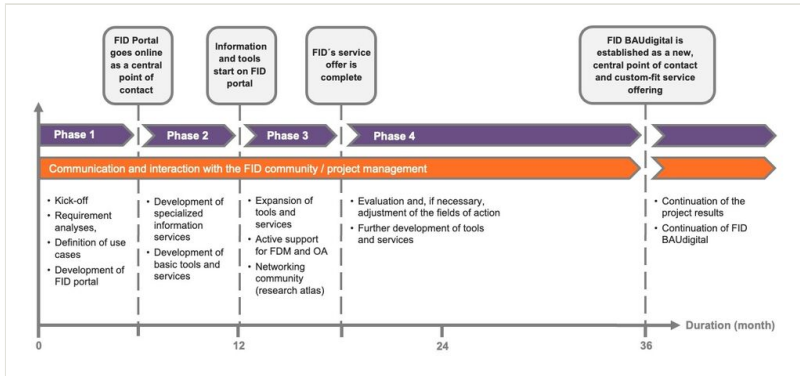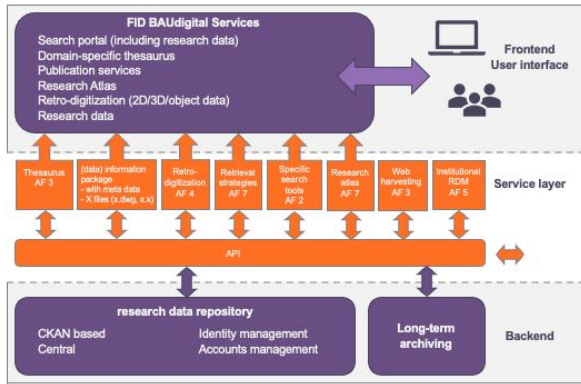
[*19] e.g. open-access.network

Figure 1.

Project schedule of FID BAUdigital.

Figure 2.

System architecture of the FID BAUdigital.