D2.5 Final Report on Project Impact

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About this document

This document is the "Final Report on Project Impact", a contractual deliverable (D2.5) of the project ARIADNE - Advanced Research Infrastructure for Archaeological Dataset Networking in Europe. The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7-INFRASTRUCTURES-2012-1) under grant agreement n° 313193.

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Acronyms of ARIADNE partners

ADS-UoY	Archaeology Data Service, University of York (United Kingdom)
AIAC	Associazione Internazionale di Archeologia Classica (Italy)
ARHEO	Arheovest Timisoara Association (Romania)
ARUP-CAS	Archeologicky ustav AV CR, Praha, v.v.i. / Institute of Archaeology of the Academy of Sciences (Czech Republic)
Athena-DCU	Athena Research and Innovation Center in Information Communication and Knowledge Technologies / Digital Curation Unit (Greece)
CNR	Consiglio Nazionale delle Ricerche institutes, CNR-ISTI and CNR-ITABC (Italy)
CSIC-Incipit	Consejo Superior de Investigaciones Cientificas / Spanish National Research Council, Institute of Heritage Sciences (Spain)
CYI-STARC	The Cyprus Institute, Science and Technology in Archaeology Research Center
DAI	Deutsches Archäologisches Institut (Germany)
DANS	Data Archiving and Networked Services, Netherlands Academy of Arts and Sciences (Netherlands)
Discovery	The Discovery Programme LBG (Ireland)
FORTH-ICS	Foundation for Research and Technology Hellas, Institute of Computer Science (Greece)
INRAP	Institut National des Recherches Archéologiques Préventives (France)
LeidenU	Leiden University, Faculty of Archaeology (Netherlands)
MiBAC-ICCU	Italian Ministry of Cultural Assets and Activities - Central Institute for the Union Catalogue (Italy)
MNM-NOK	Magyar Nemzeti Múzeum, Nemzeti Örökségvédelmi Központ / Hungarian National Museum, National Heritage Protection Centre (Hungary)
NIAM-BAS	National Institute of Archaeology with Museum of the Bulgarian Academy of Sciences (Bulgaria)
ÖAW-OREA	Österreichische Akademie der Wissenschaften, Institut für Orientalische und Europäische Archäologie (Austria)
PIN	PIN - Servizi Didattici e Scientifici per l'Università di Firenze s.c.r.l. (Italy)
SND	Swedish National Data Service (Sweden)
SRFG	Salzburg Research Forschungsgesellschaft m.b.H. (Austria)
USW	University of South Wales (United Kingdom)
ZRC-SAZU	Scientific Research Centre of the Slovenian Academy of Sciences and Arts, Institute of Archaeology (Slovenia)

1 Executive summary

This report is a deliverable (D2.5) of the project ARIADNE - Advanced Research Infrastructure for Archaeological Dataset Networking in Europe that has been funded under the European Community's Seventh Framework Programme. The document reports the final results of Task 2.5: Impact Evaluation.

The Executive Summary briefly addresses the project objectives and the framework of the impact evaluation, summarises the overall results, and gives recommendations for ARIADNE and other stakeholders with a focus on potential further advances.

ARIADNE objectives

The overall objectives of the ARIADNE project have been to mobilise many stakeholders in the sharing and (re-)use of archaeological data, and to implement e-infrastructure services that allow institutions and projects to make valuable data available to the wider community. ARIADNE thus aimed to accelerate archaeology in Europe from a starting to an advanced community in terms of data sharing capacity and integrated access to research resources. The objectives can be summarised as promoting innovation in ICT-enhanced archaeology based on sharing of data and other resources through the ARIADNE e-infrastructure (i.e. datasets, vocabularies, tools/services).

Evaluation framework

The ARIADNE project has been an EU-funded Integrating Activity based on the Integrated Infrastructures Initiatives (I3) model. According to this model the project carried out a combination of three activities, Networking and community building, Research and technical development, and Trans-national access to research centres and online services, all contributing to objectives summarised above.

For the evaluation of the impacts of ARIADNE in the Description of Work a set of indicators of success has been defined for the different project activities. This set has been employed for the impact evaluation. Furthermore the evaluation took account of broader expectations of impact formulated in the FP7 Work Programme for Research Infrastructures (2012). These include, for example, a major contribution to the structuring of the European Research Area (ERA) in the target sector, and to the co-ordinated development of research infrastructures (e-infrastructure, data repositories) for archaeology and related fields of research. Addressing also these expectations allows highlighting achievements of ARIADNE which are not obvious based on the specific set of indicators employed according to the project's Description of Work.

In this report the two sets of indicators are called "ARIADNE Impact Indicators" and "Programme Impact Indicators". Generally these sets overlap in that the activities according to the I3 model, given exceptional results, also achieve the broader expectations. The Evaluation Summary Report (Chapter 2) presents the full set of impact indicators and results, followed by chapters that describe the evaluation methodology, indicators and results in greater detail.

Overall results

The evaluation shows that ARIADNE achieved *very good results* in almost all evaluation dimensions. In particular, the project

- Accomplished its goal to implement an e-infrastructure and services for cross-searching repositories/databases of archaeological data and seed it with representative datasets of project partners;

- Achieved a large "footprint" in the sector with regard to numbers of institutions and researchers that have been reached and involved, including potential providers of additional datasets;
- Increased data interoperability based on a common model and enhanced vocabularies (i.e. ARIADNE Catalogue Data Model, extended CIDOC-CRM, vocabulary mapping tools);
- Implemented a European-level data portal providing advanced search capability with regard to archaeological subjects, locations and timespans (cultural periods);
- Made available additional high value services (i.e. 3D artefact and landscape services), and demonstrated advanced capability in making data better accessible and useful (i.e. metadata extraction from archaeological "grey literature", CIDOC-CRM based data integration).

At the core of the ARIADNE project has been the building of a European-level platform where dispersed archaeological data resources can be registered, shared, discovered and accessed. Such a platform did not exist before and its implementation arguably is the project's key innovation for the archaeological community in Europe (and beyond).

Wide reach and involvement of stakeholders

The wide reach and large direct involvement of individual researchers, practitioners, students and others (about 10,500) in activities such as needs & requirements surveys, transnational access (TNA) and other trainings, and sessions and individual presentations at sector conferences, workshops merits to be highlighted.

The conservative estimate of 10,500 participants is 30 times larger than the membership of the Computer Applications and Quantitative Methods in Archaeology (CAA) organisation/conference (350), 5 times larger than the membership of the European Association of Archaeologists (2000+), and about 32% of the number of archaeologists working in Europe (33,000), estimated by the Discovering the Archaeologists of Europe project.

Moreover the number of involved European archaeology and cultural heritage institutions (65 of 26 countries) and institutions outside Europe and international initiatives (19) appears as exceptional. The institutions have been involved in various ways, i.e. cooperation agreements, liaisons and joint activities on an informal basis; a number of agreements include contribution of datasets, given required funds are available.

Substantial results on several fronts

The project achieved substantial results on several fronts including, but not limited to, *increase* in

- Awareness of the importance of data archiving and access, including the need of appropriate archives for archaeological data,
- Exchange and transfer of knowledge in data archiving solutions and practices, possibly allowing communities that lack an appropriate archaeological data archive to "leapfrog" to an optimal solution;
- Skills development for making new as well as legacy datasets more useful and better accessible (i.e. TNA study visits to competence centres and other training);
- Mobilisation of institutions in the sharing of archaeological datasets (i.e. cooperation agreements),
- Data sharing capacity, through the ARIADNE data infrastructure,
- Services to publish, discover, visualise, access and use data for research and other purposes (i.e. ARIADNE data registry & portal, visual media and landscape services),

- Interoperability of data (i.e. ARIADNE Catalog Data Model, extended CIDOC-CRM and vocabulary mappings),
- Coordinated development of e-infrastructure initiatives in the fields of digital humanities, archaeology and heritage sciences.

High recognition at all levels

The reported advances on several fronts, achieved or enabled by the ARIADNE initiative, have been recognised by participants of trainings and professional development, research directors and national institutes, and the core institutions of both the archaeological sector and the area of research infrastructures:

- The European Archaeological Council strongly encourages institutions to participate in and share data through ARIADNE.
- The European Strategy Forum on Research Infrastructures (ESFRI Roadmap 2016) recognises ARIADNE as the core European integrator of archaeological research resources.
- Complementing the high-level recognition, testimonials of archaeology and cultural heritage institutions and researchers confirm ARIADNE's impact both at the national level, where access to data has been greatly improved in some cases, and at the European level, through the data registry/portal which allows cross-searching the improved and integrated data. Furthermore, participants in the Transnational Access (TNA) programme acknowledged the high value of the training provided for their own or institutional projects.

Thus the ARIADNE project achieved more than a large "footprint" in the sector – the project achievements are being recognised at all levels.

Conclusions and recommendations

ARIADNE has been an EU-funded Integrating Activity aimed at overcoming a situation of dispersed and isolated archaeological data resources. The project has achieved essential results that allow data sharing, interoperability and accessibility for research across institutional and national as well as disciplinary boundaries.

The evaluation results demonstrate that the ARIADNE project has a *strong* impact in the field of archaeological research and data management in Europe, and that this may become a *lasting* impact. The results are encouraging and a solid basis for taking appropriate next steps.

The evaluation concludes that based on the project results there is a *high potential for further advances* based on sharing of data and other resources through the ARIADNE e-infrastructure.

The period of EU support for the ARIADNE project ended. However the not-for-profit ARIADNE Association has been set up to enable continued operation of the current dataset registry and access portal, further community networking and offering training for potential data providers.

To realise the full potential of the implemented data infrastructure and portal for the archaeological research community, it is necessary to keep the momentum, incorporate additional datasets, and ensure the sustainability of the e-infrastructure operation. Therefore a number of recommendations are given for stakeholders in the ARIADNE initiative:

Institutional stakeholders

ARIADNE provides a common platform for archaeological data publication, discovery and access. The platform is a community asset which, however, requires sustained efforts for maintenance and extension. Therefore all institutional stakeholders in accessible archaeological data, i.e. professional associations, research institutes and funding agencies, should consider

- Utilizing the platform for own and community wide purposes (i.e. open sharing of data as increasingly demanded by funding bodies);
- Supporting the platform by making available resources and/or mobilising data providers (i.e. datasets of institutions from countries not yet present on the ARIADNE portal);
- Delegation of a representative to the ARIADNE Association to express and promote common interests in the continuation of the e-infrastructure and other activities (i.e. open data advocacy, training and professional development).

ARIADNE initiative

For the ARIADNE initiative, represented by the ARIADNE Association, the following recommendations can be given:

- *Training offer:* Focus on providing training for potential providers of new datasets (i.e. curators of institutional legacy databases and major new projects); align with the knowledge transfer for new archaeological data archives (i.e. the SEADDA initiative).
- *Maintenance of the current services:* Keep the current services running, including basic maintenance and updates (if required), until new funding for extension of datasets and services are acquired, for example in a follow-up project.
- *Incorporation of new datasets:* Attempt to incorporate new datasets based on specific arrangements and/or according to the availability of own or external funds. A number of institutions have expressed their interest to use the data registry and portal for publishing datasets.
- *Project based sustainability:* Substantial extension of resources (datasets, tools/services) and continued sustainability will require a series of funded projects or dedicated national or international funding commitments.
- *Long-term sustainability:* An approach for long-term sustainability of the e-infrastructure and services could be a foundation, endowed with and/or renewed significant funding. Another option could be that an ESFRI Research Infrastructure of the humanities and heritage sciences sector (DARIAH, E-RIHS) takes up the e-infrastructure and adapts and utilizes it to support research communities, including archaeological researchers.

These recommendations are generally in line with the ARIADNE sustainability plan that is included in the ARIADNE Final Innovation Agenda and Action Plan (D2.4, November 2016).

2 Evaluation summary report

2.1 ARIADNE objectives

The overall objectives of the ARIADNE project have been to mobilise many stakeholders in the sharing and (re-)use of archaeological data, and to implement e-infrastructure services that allow institutions and projects to make valuable data available to the wider community. More specifically the project aimed to

- build a community of stakeholders in the sharing and (re-)use of archaeological data (data providers, service developers and users),
- integrate archaeological datasets held by different digital archives and help overcome data fragmentation and lack of interoperability,
- provide a common access point to the distributed data resource and new services/tools for accessing and using the data,
- offer data-related guidance and training (e.g. guides to good practice, transnational study visits and other training),
- promote innovation in digital archaeology based on shared datasets, data models and vocabularies, and advanced or new tools and services.

The broader objectives of ARIADNE according to the FP7 Work Programme for Research Infrastructures include contributions to the structuring of the European Research Area (ERA) in the target sector of archaeology and closely related disciplines, and to the co-ordinated development of research infrastructures (e-infrastructure, data repositories) for these disciplines in Europe. ARIADNE thus aimed to accelerate archaeology in Europe from a starting to an advanced community in terms of integrated digital research resources and services.

2.2 Evaluation framework

The framework of the impact evaluation comprises of the different dimensions in which the project intended to make a difference, the various types of impacts envisaged, and the defined indicators (evidence) for these impacts. This framework is largely determined by the fact that ARIADNE has been funded as an Integrating Activity project under the European Union's Seventh Framework Programme for Research and Technological Development (FP7), specifically the Research Infrastructures programme.

The Integrating Activity scheme prescribes that projects have to carry out a defined set of activities, Networking activities, Trans-national access and/or service activities, and Joint research activities. The second core element of the impact evaluation framework is that ARIADNE set out to build an e-infrastructure which integrates and provides access to data from different digital archives for archaeological research. The main objective of the data infrastructure is to allow researchers and other users a wider and more efficient access to archaeological datasets.

For the evaluation of the impacts of ARIADNE, in the Description of Work (Grant Agreement) a set of indicators of success has been defined for the different project activities; this set has been employed for the impact evaluation. Furthermore the evaluation takes account of a number of expected broader impacts of Integrating Activities stated in the relevant FP7 Work Programme for Research Infrastructures (2012). Indeed, addressing also these impacts allows highlighting achievements of ARIADNE which are not obvious based on the specific set of indicators employed according to the project's Description of Work.

The focus of the evaluation is on innovations achieved or enabled by project outcomes in the field of archaeological research, for example, the community building for sharing datasets through e-infrastructure, the implemented data infrastructure and services, demonstrated innovative capabilities enabled by the shared resources (datasets, models, vocabularies, tools/services), training for skills development in data-related tasks and tools.

At the core of the ARIADNE project has been the development of an e-infrastructure platform where dispersed archaeological data resources can be described, shared, discovered and accessed. Such a platform did not exist before and its implementation arguably is the project's key innovation for the archaeological community in Europe (and beyond). But it should be noted that the project evaluation concerns mainly the implementation phase rather than the regular operation phase of the data infrastructure and services (which is not part of the current grant agreement). However, available results such as usage figures of the ARIADNE portal, publicly launched end of March 2016, are of course reported.

Economic, social and environmental impacts are generally not considered. These are included neither in the specific ARIADNE indicators nor the broader Work Programme indicators. Such indicators like economic prosperity, job generation, quality of life, social cohesion and environmental sustainability mainly concern potential regional impacts of the building and operation of major single-sited research infrastructures (e.g. large natural or life sciences facilities).

2.3 Three views of project achievements

This section summarises and highlights some of the results of the impact evaluation. The presentation is organised as follows:

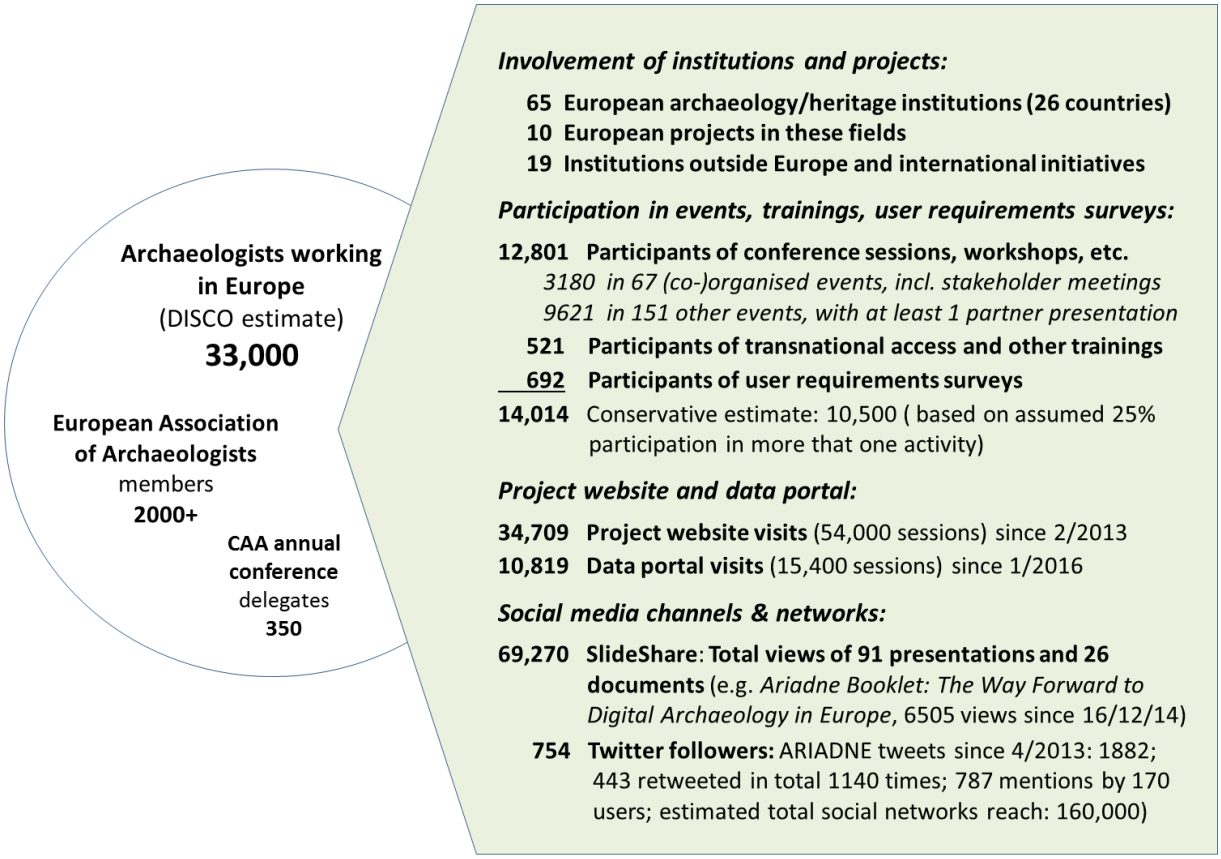
- *ARIADNE "footprint":* The project footprint in the archaeological domain is presented based on figures of the participation of individual researchers and practitioners in various ARIADNE activities (e.g. surveys, conference sessions, trainings) and results of dissemination activities.
- *High-level recognition of ARIADNE:* Recognition of ARIADNE as the core integrator of archaeological data in Europe by the leading organisations in both the archaeological sector and the area of research infrastructures, the European Archaeological Council and the European Strategy Forum on Research Infrastructures, respectively.
- *Statements of project-external institutions and researchers:* Complementing the high-level recognition, statements of archaeology and cultural heritage institutions and researchers confirm ARIADNE's impact both at the national level, where access to data has been greatly improved, and at the European level through the data registry/portal that allows cross-searching the improved and integrated data. Furthermore, participants in the Transnational Access (TNA) programme and other professional development acknowledge the high value of the training provided for their own or institutional projects.

Thus the ARIADNE project achieved more than a large "footprint" in the sector – the project achievements are being recognised at all levels.

2.3.1 The ARIADNE footprint

ARIADNE addresses the archaeological research, data and ICT community, particularly those with an interest in sharing and using data through digital infrastructure and services. Many stakeholders, institutions and individuals, have been reached and involved in project activities. A large footprint in the sector has been achieved. ARIADNE involved 65 European archaeology/heritage institutions of 26 countries and 10 European projects through cooperation agreements and memoranda as well as

cooperation on an informal basis. Furthermore 19 institutions outside of Europe and international projects have been involved through liaisons, cooperation agreements or joint activities on an informal basis. The following figure can give an impression of ARIADNE's footprint in the sector based on these figures, direct participation of individual researchers and practitioners in various ARIADNE activities, and results of other dissemination activities.



Compared to available figures for the archaeological community the total of participation in events, trainings, user requirements surveys (conservative estimate 10,500) represents a large footprint of ARIADNE in the community. The Discovering the Archaeologists of Europe (DISCO) project[1] estimates *"that approximately 33,000 archaeologists now work across Europe as a whole"* (DISCO 2014: 6). This figure includes archaeologists employed at scientific/academic and other institutions as well as at archaeological businesses (contract archaeologists and consultancies).

The European Association of Archaeologists (EAA) has over 2000 regular members from (mostly) Europe and worldwide (Criado-Boado 2016). The EAA Annual Meeting 2014 in Istanbul, *"by far the best attended in EAA's history"* (EEA 2014c: 3), welcomed 2062 delegates, 1655 (80%) delegates came from European countries[2].

The core conference for archaeology and ICT arguably is the annual Computer Applications and Quantitative Methods in Archaeology (CAA) conference. The CAA organisation notes, *"Over the last*

[1] Discovering the Archaeologists of Europe (EU, Leonardo da Vinci II, 2006-8; Lifelong Learning Programme, 2012-14), http://www.discovering-archaeologists.eu

[2] EAA 2014 attendance (EAA 2014c: 7-8): 1655 delegates from European countries: EU28 (1545), other European countries (110), including Norway (59), Serbia (21), Switzerland (15), Albania, Bosnia and Herzegovina, FYR Macedonia, Iceland, and the Vatican. 215 delegates from other Eurasian countries: Turkey, the host country of the conference (145), Russia (56), Ukraine (6), Armenia, Azerbaijan, Georgia, Kazakhstan. 192 from other world regions: e.g. USA (117), Canada (13), Australia (28), Israel (12), Japan (8), and others.

forty years CAA has grown from an annual event at the University of Birmingham to a national and now worldwide conference attracting over 300 participants every year"[3]. The latest conference in Oslo drew about 350 delegates, mostly from Europe and the United States[4].

The total number of end-users who participated in ARIADNE surveys, study visits and other trainings, and events (co-)organised by partners or where they gave presentations is 14,014. We assume that it includes 25% participation of people in more than one activity, hence that ARIADNE directly reached and involved 10,500 end-users.

Thus the number of researchers, practitioners, students and other people involved is 30 times larger than the membership of the Computer Applications and Quantitative Methods in Archaeology (CAA) organisation/conference (350), 5 times larger than the membership of the European Association of Archaeologists (2000+), and about 32% of the number of archaeologists working in Europe (33,000), estimated by the Discovering the Archaeologists of Europe project (DISCO 2014: 6).

2.3.2 High-level recognition

The core institutions of both the archaeological domain and the research infrastructures domain acknowledge ARIADNE's success.

The European Archaeological Council (EAC)[5] strongly encourages organisations to participate in the ARIADNE initiative. The EAC comprises of heads of national services responsible under law for the management of the archaeological heritage in the Council of Europe member states. In their Amersfoort Agenda, setting the agenda for the future of archaeological heritage management in Europe, the Council emphasises *"the need to share, connect and provide access to archaeological information with the help of digital technologies. The key to this aspiration is to improve collaboration – we need to share rather than exchange. It is essential to encourage the development of European data-sharing networks and projects in the field of archaeology. The ARIADNE project is an excellent European initiative in this regard and participation in this project should be strongly encouraged"* (European Archaeological Council 2015: 21).

The European Strategy Forum on Research Infrastructures (ESFRI)[6] in their Roadmap 2016 acknowledges ARIADNE's role as the leading integrator of archaeological research data infrastructures (i.e. data repositories): *"In the archaeological sciences the ARIADNE network developed out of the vital need to develop infrastructures for the management and integration of archaeological data at a European level. As a digital infrastructure for archaeological research ARIADNE brings together and integrates existing archaeological research data infrastructures so that researchers can use the various distributed datasets and technologies"* (ESFRI 2016: 52 and 175).

Moreover the ESFRI Roadmap 2016 highlights ARIADNE as a background of the European Research Infrastructure for Heritage Science (E-RIHS)[7], newly placed on the Roadmap: *"Heritage Science has brought about the need of structuring the net of infrastructures operating throughout Europe. Fragmentation, duplication of efforts, isolation of small research groups put at risks the competitive advantage of European heritage science research, promoted so well by the unique cultural heritage. The long-term tradition of this field of research, the ability to combine with innovation, and the integration promoted by EU-funded projects such as EU-ARTECH, CHARISMA and IPERION CH in conservation science, and ARIADNE in archaeology represent the background of E-RIHS"* (ibid. 52).

[3] CAA International, http://caa-international.org/about/history/

[4] cf. CAA 2016 Oslo: Storymap - participants, http://caaconference.org/storymap/

[5] European Archaeological Council (EAC), http://european-archaeological-council.org

[6] European Strategy Forum on Research Infrastructures (ESFRI, http://www.esfri.eu

[7] European Research Infrastructure for Heritage Science (E-RIHS), http://www.e-rihs.eu

Thus ARIADNE is recognised as the leading integrator of archaeological data in Europe by the core organisations in both the archaeological sector and the area of research infrastructures. The European Archaeological Council strongly encourages institutions to participate in and share data through ARIADNE. The European Strategy Forum on Research Infrastructures (ESFRI Roadmap 2016) acknowledges ARIADNE as the core European integrator of archaeological research resources (i.e. data archives); furthermore this integration is recognised as an important background of the new ESFRI Roadmap initiative E-RIHS - European Research Infrastructure for Heritage Science.

2.3.3 ARIADNE achievements perceived by researchers and institutions

Complementing the high-level recognition of ARIADNE, statements of individual researchers and institutions confirm the appreciation and impact of the project results.

User needs and requirement surveys

ARIADNE conducted two international online surveys to receive information about user needs and requirements for data infrastructure and services and expectations from the project (ARIADNE 2014a). 692 researchers, directors of research institutes and repository managers provided substantial input (total participants: 881). We reproduce a couple of statements from the feedback:

- *"Ariadne seems like a great idea, it is such a pity that so many repositories and data are not shared by wider communities, for developing new ideas, teaching, creating new collaborations, sharing the competence of each other"* (data manager, Norway).
- *"This is a splendid initiative - and I hope that it will reap the fruits we all wish!"* (research director, Malta).
- *"The main objectives of Ariadne project are important to develop archaeological research in the European Union. I hope the Ariadne project achieves some objectives"* (researcher, Portugal).
- *"The ARIADNE project addresses major issues of archaeological data. Many archaeologists are waiting for the results of this project"* (researcher, France)
- *"Thanks for this ARIADNE initiative; if it can get into operation, it will be a tremendous asset"* (researcher, UK).

These expectations from and hopes for ARIADNE were stated about 10 months after the start of the ARIADNE projects.

Recognition of ARIADNE's impacts by institutions and researchers

In the final project event in December 2016 we heard, among others, the following statements collected by partners from project-external researchers, research directors, cultural heritage agencies and others on the impact of ARIADNE[8]:

- *"The ARIADNE project made it possible for the Archaeological Map of Bulgaria to become known on the international level through improved data management, mapping and sharing. All this is useful for both national and international researchers"* – Bulgarian Ministry of Culture.
- *"The on-line Inrap documentary data on the ARIADNE platform represents a considerable step forward for the French archaeological community. The next step is putting online information systems containing the primary data. We hope to contribute jointly with the Consortium Memory*

[8] ARIADNE Final Conference: Success stories from partners and the research community [presentations], http://www.ariadne-infrastructure.eu/Events/ARIADNE-Final-Conference

of Archaeologists and Archaeological Sites (MASA) from the Very Large Facility Huma-Num" – Xavier Rodier, Ingénieur de Recherche, CNRS, France.

- "*The HNM Archaeology Database became the most comprehensive online database in Hungary and has a profound effect on teaching, research, data management and informing developers and the public"* – Forster Gyula National Centre for Cultural Heritage Management, Hungary.
- *"The work of the ArheoVest team has materialized in standardization of archaeological site sheets, their model being taken at national level by the RAN System [National Archaeological Repertoire]"* – Arhg. Dr. Victor Bunoiu, expert adviser, Country Directorate for Culture Timis, Romania.
- *"From TII's perspective, our project with the Discovery Programme, ARIADNE and the Digital Repository of Ireland, is very significant, as it establishes a framework for the validation, long term curation and dissemination of our data sets especially the archaeological excavation reports. The expertise developed through ARIADNE, has helped to ensure that this data set can easily be integrated with other archaeological data sets, be it in Ireland or abroad. This will unlock the significant research that has been captured in the 'grey literature' within a European context, which in turn will enable new models and frameworks to be explored and tested."* – Ronan Swan, Head of Archaeology, Transport Infrastructure Ireland.
- *"The ARIADNE portal, thanks to its innovative technology, is expected to become an indispensable tool for the development of the scientific activities in the field of archaeology. In fact, it collects and integrates, for the first time and on the basis of information technology protocols internationally shared, the digital data provided by groups or individual scholars from all around the world that would hardly have been possible to find using traditional methods. With this approach, you will allow the researcher to be able to have a large amount of information and to relate to each other and the data: with the perspective to elaborate scientific analysis in an organic and comprehensive manner"* – Professor Angelo Pellegrino, Head of the Archaeological Area of Ostia, Italy.

These statements highlight and confirm the effects of ARIADNE both at the national level, where access to data has been greatly improved, and at the European/international level, through the data registry/portal which allows cross-searching the improved and integrated data.

Effects of transnational access (TNA) study visits and other training

ARIADNE partners offered transnational access (TNA) study visits to their research centres (summer schools, individual visits) and other training opportunities (short training courses, tutorials, etc.). Over 500 mostly young researchers participated. The following examples illustrate effects of ARIADNE trainings:

- *"The course gave me a very good overview on how metadata can be organized, and suggested some good tools that can help me to carry out my project. I also got in contact with other people in the field that share my problems with metadata management, and we will have the possibility to share our future experience and solutions"* (researcher, Belgium).
- *"I have often worked alongside people using different methods of 3D recording, but never actually completed it myself; I now feel that I have the knowledge and understanding to undertake this type of work myself"* (researcher, Ireland).
- *"The main achievements experienced during the summer school are related to the possibility to manage and handle 3D models from pictures: this means that in a very short time it would be possible to document archaeological features, and share them very easily"* (researcher, Italy)

- *"The experience of visiting ADS for two weeks and working through the documentation and archiving of the Pergamon dataset was invaluable in helping us set up IANUS, the German national digital repository for archaeology"* (data manager, Germany).

These are achievements of individual researchers and data managers enabled by ARIADNE which, in turn, will contribute to wider access to shared high-quality data.

2.4 ARIADNE impact indicators and results

For the evaluation of the impacts of ARIADNE a set of indicators of success has been defined for the different project activities according to the I3 model of Integrating Activities and included in the Description of Work (Part B, section 3, pp. 55-56). This set of indicators we call the "ARIADNE impact indicators". The following sections present and summarise the results of the project evaluation for these indicators.

2.4.1 Community building for innovation through e-infrastructure

The overall goal of ARIADNE activities in this category has been involving many stakeholders (institutions and end-users) from Europe and beyond, and fostering cooperation with research institutions and projects on a range of vital topics and resources in the context of the ARIADNE e-infrastructure (i.e. sharing of datasets, vocabularies, tools/services).

Key results

- *Involvement of domain institutions in Europe:* The project involved 65 European archaeology and cultural heritage institutions of which at least one, often more institutions are present of 24 of the 28 EU Member States and two other European countries (Iceland, Norway); the figure includes 17 ARIADNE partners in the relevant categories. Yet to be involved in the ARIADNE initiative are archaeological institutions in Croatia, Latvia, Luxembourg and Slovakia.
- *Type and focus of involvement:* The institutional stakeholders have been involved based on formal cooperation agreements (15) and through liaison and cooperation on an informal basis. These mostly concerned the building and sharing of databases, use of common vocabularies (e.g. thesauri), and expertise in special subject matters (i.e. digital archiving). Institutions also sent researchers to participate in ARIADNE Transnational Access (TNA) trainings for institutional projects (i.e. in view to provide data to ARIADNE).
- *Cooperation with European archaeology and cultural heritage projects:* During the project period ARIADNE cooperated with 10 European projects on an informal or formal basis (e.g. Memorandum of Understanding). Among these EU funded projects are other research (e-) infrastructure projects, i.e. CENDARI (history), DARIAH (digital humanities), E-RIHS (new ESFRI RI initiative), PARTHENOS cluster) as well as domain projects, i.e. ArchaeoLandscapes (remote sensing technologies and data) or NEARCH (public archaeology).
- *Selected cooperation highlight:* Particularly noteworthy with regard to the co-ordinated evolution of research e-infrastructures are foreseen joint dataset registration and access services for humanities, archaeology and heritage sciences data, i.e. harmonization of data catalogues following and extending the model developed by ARIADNE.
- *Involvement of institutions outside Europe and international initiatives:* ARIADNE established liaisons and collaborative activities with 19 institutions outside of Europe and international projects (six formal cooperation agreements). The spectrum of institutions and projects ranges from national and international authorities (i.e. Israel Antiquities Authority, ICCROM) to special

interest groups (i.e. CAA Linked Data SIG) and specific data and vocabulary resources (i.e. MAGIS - Mediterranean Archaeology GIS; PeriodO); also data collection, archiving and access systems has been a major topic (i.e. FAIMS Australia, Open Context and tDAR in the United States).

- *Selected cooperation highlight:* With regard to data linking the collaboration with PeriodO merits to be highlighted. Through the PeriodO system ARIADNE made available a set of cultural periods for over 20 European countries with unique identifiers (URIs). These allow stable linking and integration of data and are now available for institutions and projects worldwide.
- *Going beyond Europe:* ARIADNE partners have initiated and support the North African Heritage Archive Network (NAHAN). The initiative aims to mobilise and share archival information about archaeological investigations in North Africa. This is being implemented based on a catalogue hosted by the German Archaeological Institute from which records will be provided to the ARIADNE registry/portal.
- *Participation of community members (end-users) in project activities:* ARIADNE partners reported participation of in total 14,014 project-external scholars, post-gradual researchers, practitioners and others in different activities. These were user requirements surveys (692 participants), trans-national access (TNA) and other training offers (521), 67 international and national conference sessions and workshops (co-)organised by partners (3180) and 151 others attended by partners giving at least one presentation (9621). However, it is assumed that the total number of 14,014 includes 25% participation of people in more than one activity; hence a more conservative estimate is about 10,500.
- *ARIADNE "footprint" in the European archaeology sector:* The figure of 10,500 people *directly* reached and involved through different ARIADNE activities is 30 times larger than the membership of the Computer Applications and Quantitative Methods in Archaeology (CAA) organisation/ conference (350), 5 times larger than the membership of the European Association of Archaeologists (2000+), and about 32% of the number of archaeologists working in Europe (33,000), estimated by the Discovering the Archaeologists of Europe project.
- *Innovation Agenda and Action Plan:* The project has issued a comprehensive agenda and action plan for further advances in open sharing of data and digital archaeology. Institutions and individuals are invited to consider recommended actions that are relevant to their different mission and activities (i.e. R&D, data archiving, education & training). The agenda and action plan is carried forward by the not-for-profit ARIADNE Association (formally established in November 2016). The planned activities of the ARIADNE Association include continuation of community networking, TNA training, and research liaisons established during the project. Furthermore, the association will seek opportunities to extend the ARIADNE registry and portal with datasets of new providers and additional services.

Summary of results

ARIADNE has achieved a strong *community building for innovation* in data-related practices through cooperation agreements and informal liaisons and activities with archaeological and other cultural heritage institutions in Europe and beyond. ARIADNE has mobilised and involved many institutions, projects and individuals through various activities. These include surveys on sector needs with regard to data resources and services, conference sessions and workshops on ARIADNE topics, training courses, among others. Awareness of the importance of sharing data through research e-infrastructure (i.e. data archiving and federation) has been raised and a community of organisations that engage in data sharing has emerged. Also initiatives for new e-infrastructures such as national digital archives for archaeological data have been encouraged. Joint ownership of the ARIADNE e-infrastructure and services has been fostered.

Involvement of archaeological and cultural heritage institutions in Europe

ARIADNE set out to involve institutional stakeholders of all EU Member States, particularly European antiquity/heritage authorities, archaeological and other heritage research centres, university departments/institutes, and research and professional associations; the category does not include technological research & development organisations.

The project involved 65 European institutions of which at least one, often more institutions are present of 24 of the 28 EU Member States and two other European countries (Iceland, Norway); the figure includes 17 ARIADNE partners in the relevant categories.

Yet to be involved in the ARIADNE initiative are archaeological institutions in Croatia, Latvia, Luxembourg and Slovakia. These countries have relatively small numbers of archaeologists, i.e. 60 in Latvia or over 200 in Slovakia, compared to over 800 on Portugal or Romania, or over 4000 in Germany or Italy (cf. DISCO 2014: 18).

The institutional stakeholders have been involved based on formal cooperation agreements (15) and through liaison and cooperation on an informal basis. These mostly concerned the building and sharing of databases, use of common vocabularies (e.g. thesauri), and expertise in special subject matters (i.e. digital archiving, scientific datasets, application of the CIDOC-CRM ontology). Institutions also sent researchers to participate in ARIADNE Transnational Access (TNA) trainings for institutional projects (i.e. in view to provide data to ARIADNE).

Cooperation with European archaeology and cultural heritage projects

During the project period ARIADNE cooperated with 10 European projects on an informal or formal basis (e.g. Memorandum of Understanding). Among these EU funded projects for example are ArchaeoLandscapes, CENDARI (e-infrastructure for European history archives), DARIAH (digital humanities), EUROPEANA (Europeana Research), NEARCH (public archaeology), PARTHENOS (humanities e-infrastructures cluster), and the new ESFRI initiative E-RIHS (heritage sciences).

The cooperation topics include common policies and interoperability of e-infrastructures, heritage sciences (focus on tangible heritage), specific datasets/content archives and standards, and tools/services needed by researchers in the digital humanities, including e-archaeology. Furthermore, public archaeology (NEARCH project) and skills development in an area not covered by ARIADNE trainings: remote surveying techniques and data (ArchaeoLandscapes project).

Particularly noteworthy with regard to the co-ordinated evolution of research e-infrastructures are foreseen joint dataset registration and access services for humanities, archaeology and heritage sciences data, i.e. harmonization of data catalogues following and extending the model developed by ARIADNE.

Involvement of institutions outside Europe and international initiatives

ARIADNE established liaisons and collaborative activities with 19 institutions outside of Europe and international projects; formal cooperation agreements have been signed with 6 institutions/ projects. The spectrum of institutions and projects ranges from national and international authorities (i.e. Israel Antiquities Authority, ICCROM) to special interest groups (i.e. CAA Linked Data SIG) and specific data and vocabulary resources (i.e. PeriodO).

Most liaisons focused on sharing of reports and datasets from archaeological surveys, excavations and conservation projects (i.e. American School of Classical Studies in Athens, ICCROM, MAGIS - Mediterranean Archaeology GIS); exchange of expertise in data archiving and access (i.e. Open Context and tDAR in the United States), and use of common vocabularies and data linking based on W3C recommended Linked Data standards (i.e. Nomisma, Pelagios, PeriodO).

Collaborative activities have achieved important results for advancing data sharing and integration in Europe and beyond. For example, the circulation of archiving expertise has been increased in dedicated events involving European and other digital archive providers. With regard to data linking the collaboration with PeriodO merits to be highlighted. Through the PeriodO system ARIADNE made available a set of cultural periods for over 20 European countries with unique identifiers (URIs). These allow stable linking and integration of data and are now available also for other projects in Europe and beyond.

Participation of end-users in project activities

Many more potential end-users of ARIADNE results than expected participated in project activities. Instead of a few hundred end-users 10,500 participated in project activities. This figure does not include people reached through online dissemination of project results.

A large number of end-users (692) participated in the user needs & requirements surveys. The surveys allowed the project gain a good understanding of user needs and expectations from the ARIADNE e-infrastructure and services, which have been developed accordingly. 521 researchers and practitioners benefited from transnational access (TNA) study visits at ARIADNE competence centres (summer schools and individual visits) and tutorials and short training courses at various events. In 67 conference sessions and workshops (co-)organised by ARIADNE partners presented and discussed with participants on-going work and results of the project, with a total of 3180 project external participants reported by partners. Others learned about ARIADNE's work and achievements through individual presentations of partners at 151 other international and national events, with a total of 9621 participants reported.

These figures amount to 14,014 people reached and involved by ARIADNE in surveys, TNA study visits and other trainings, and presentations and discussion of project results at various events. However, we assume that this number includes 25% participation of people in more than one activity. Therefore we estimate that ARIADNE reached and involved about 10,500 researchers, practitioners, students, and others. According to the types of activities these were people active or interested in archaeological and cultural heritage research and dissemination, particularly with digital content/data, tools and services.

Innovation Agenda & Action Plan and Sustainability Plan

The ARIADNE Innovation Agenda and Action Plan provides a comprehensive set of focus areas and suggested activities on how to advance open access digital archaeology in Europe over the next 5-10 years (ARIADNE 2015b and 2016a). In the 5-year horizon it covers Research e-infrastructures services, tools and other resources, Data archiving and curation, Open data sharing and re-use, and Capacity building for open access digital archaeology. Furthermore, in the 10-year innovation horizon, several other potential advances towards innovative digital archaeology are suggested.

Given the broad range of the Innovation Agenda and Action Plan the institutional members of the ARIADNE consortium and affiliated institutions have not been asked to endorse it. This would have been inappropriate as the institutions have different missions and activities (e.g. research & development, data archiving and sharing, education and training). Instead members of the institutions are invited to join the not-for-profit ARIADNE Association that has been formally established in November 2016. The membership is on an individual and not institutional basis, because it is often difficult for institutions, especially large public ones, to participate in such an organisation.

The ARIADNE Association focuses on continuing the activities of the EU-funded ARIADNE project based on the Sustainability Plan (ARIADNE 2016a: Section 4.7). The planned activities include further community networking (i.e. meetings at international conferences), continuation of TNA training

(provided "in-kind" by ARIADNE competence centres) and research liaisons established during ARIADNE. Furthermore, the Association will seek opportunities to extend the ARIADNE Registry and Portal with new datasets and additional services. The basic operation of the facilities will be maintained by the largest ARIADNE partner CNR "in-kind" (at least for 5 years). The ARIADNE Registry and Portal will be extended with additional datasets and functionality if new funds can be acquired.

2.4.2 Promotion of awareness & good practices

The overall goal of ARIADNE activities in this category has been wide dissemination of information on the project goals and results as well as opportunities to cooperate with and benefit from the ARIADNE initiative, i.e. conference sessions and workshops, training programmes, guides to good practice research data, and others.

Key results

- *Event organisation and participation:* About 9,600 people of relevant communities participated in conference sessions, workshops and special meetings (co-)organised by ARIADNE and individual presentations of project partners at other events; in total 12,801 project-external participants in 218 events were reported, but it is assumed that this figure includes 25% participation of people in more than one event.
- *Reach of project website:* Between February 2013 and December 2016 there were 53,849 sessions by 36,611 website visitors with a total of 184,074 page views (the target was 12.000 website visitors).
- *Social media channels:* ARIADNE has 754 followers on Twitter. Of 1882 tweets by ARIADNE since April 2013, 443 (23.5%) have been retweeted in total 1140 times. There have been 787 mentions of ARIADNE by 170 twitter users. In total ARIADNE's social networks have 11,500 members with a reach of around 160,000 followers (the target was 15,000 members).
- *Dissemination of information materials:* ARIADNE has produced and disseminated various information materials, including booklets on project goals and achievements (2014, 2016), newsletters, leaflets and flyers (e.g. training offer, available services and tools). One particularly popular product is the first booklet *ARIADNE - The Way Forward to Digital Archaeology in Europe*, which since December 2014 received over 6500 views on SlideShare. The periodic project newsletter (nine issues) has 410 subscribers (the target was 300).
- *Online dissemination of presentations and documents:* ARIADNE made 91 presentations and 26 documents (i.e. deliverables) available on SlideShare which in total received 69,270 views.
- *Guides to Good Practice:* The guides and case studies produced with support by ARIADNE received around 2000 unique page views on the ADS website (the target was 1500 visitors). So far the most accessed is the Dendrochronology Data guide (published in June 2015) with 1275 page views; however the 3D Datasets guide, published in December 2016, already has had over 400 page views.
- *Research publications:* ARIADNE researchers reported in total 86 project-related papers published in journals, conference proceedings, books and other publications. Among the latest publications is a multi-authored paper on the ARIADNE E-infrastructure (Meghini *et al*. 2017) in a special issue of the Journal on Computing and Cultural Heritage, edited by leading researchers of the project. Also particularly noteworthy is the paper *Enabling European Archaeological Research: The ARIADNE E-Infrastructure* in the proceedings of the European Archaeological Council - Symposium 2016 in the e-journal Internet Archaeology (Aloia *et al*. 2017).

Summary of results

Events organisation and participation

ARIADNE partners presented the project work and results and networked with participants at 218 events, with a total of 12,801 participants. The events were conferences and workshops in three categories: events for researchers, practitioners, students in the field of archaeology and cultural heritage (non-digital focus); for researchers, developers and advanced users in digital archaeology, heritage and humanities; and for developers/providers and institutional users of research e-infrastructure as well as research policy and funding bodies. Furthermore there were a number of events ranging from meetings with high-level officials to events involving schools in archaeological activities.

67 of the events were (co-)organised sessions or workshops at conferences and special meetings with representatives of institutions and projects to liaise and establish or advance cooperation (3180 participants). Furthermore partners presented ARIADNE and their project contributions at 151 other events (9621 participants). Not included in these figures are transnational summer schools and short training courses and tutorials.

The number of 12,801 is the total of project external participants of (co-)organised conference sessions, workshops, meetings and individual presentations at other events reported by project partners. We assume that the total includes 25% participation of people in more than one event. Thus the estimated total participation is 9600.

Project website and social media

Project website: At least 12,000 website visitors have been expected (indicator of success), but over 36,000 consulted the project website; also the numbers of sessions (about 54,000) and page views (184,000) are quite high. The web statistics show that the ARIADNE website has a European and international user base; about 75% of the visitors were located in Europe.

Social media: Such media have not been considered in the impact indicators, although they play an ever greater role in the dissemination of project information. Indeed, ARIADNE achieved a large distribution of project information and recognition through social media platforms (SlideShare, Twitter). ARIADNE has a Twitter account since April 2013 and at present 754 followers. Of 1882 ARIADNE tweets 443 (23.5%) have been re-tweeted in total 1140 times. There have been 787 mentions of ARIADNE by 170 Twitter users. In total ARIADNE's social networks have 11,500 members with an estimated reach of around 160,000 followers.

Dissemination of information material

The project has disseminated a set of information material which includes project booklets, newsletters, posters, leaflets and flyers. All material except the newsletter has been disseminated in physical and digital form. An audience of 3000 was expected (indicator of success), which certainly has been surpassed. For example, the first project booklet *ARIADNE - The Way Forward to Digital Archaeology in Europe* since December 2014 received over 6500 views on the ARIADNE SlideShare account, the *ARIADNE Introduction* presentation over 3500 views.

Over 150 project news and announcements have been disseminated online. This included the periodic project newsletters (9 issues), published online and disseminated to 410 subscribers. Two project booklets have been produced and disseminated at conferences and online: *ARIADNE - The Way Forward to Digital Archaeology in Europe* (97 pages) and *ARIADNE – Building a Research Infrastructure for Digital Archaeology in Europe* (63 pages). Other edited print and online products included: a project leaflet in two editions (2013, 2016), and flyers to advertise trainings and products:

i.e. calls for TNA study visits, presentation of available tools and services. These have been disseminated at international and national events (i.e. CAA, EAA, CHNT) as well as online.

Guides to good practice

ARIADNE has promoted good practices in the creation, documentation and archiving of archaeological datasets. The project has initiated and supported the development of four guides to good practice and three case studies. These already are or will shortly be accessible in the online *Guides to Good Practice* of Archaeology Data Service & Digital Antiquity. The guides concern 3D Datasets, Reflectance Transformation Images (RTI) Datasets, Dendrochronological Data, and Thermoluminescence Dating; one case study addresses the selection and documentation of datasets of "big data collections" and two others complement the 3D and Dendrochronology guides with real-world worked examples. Between August 2013 and January 2017 the already published guides and case studies received about 2000 unique page views. So far the most accessed is the Dendrochronology Data guide (published in June 2015) with 1275 unique page views; however the 3D Datasets guide, published in December 2016, already has had over 400 unique page views.

Research publications and other products

ARIADNE researchers reported in total 86 project-related articles published in journals, conference proceedings, books and other publications; the list of articles is included in the final report on project dissemination (ARIADNE 2017a). The publications include special journal issues and proceedings on ARIADNE topics such as Open Access & Open Data (Archäologische Informationen, Vol.38/2015, in English), CIDOC-CRM extension and application (EMF-CRM Workshop 2015, CEUR-WS/Vol.1656), and Research E-Infrastructures.

Among the latest publications is a multi-authored paper on the ARIADNE e-infrastructure (Meghini *et al*. 2017) in a special issue of the Journal on Computing and Cultural Heritage, edited by leading researchers of the project. Also particularly noteworthy is the paper *Enabling European Archaeological Research: The ARIADNE E-Infrastructure* in the proceedings of the European Archaeological Council - Symposium 2016 in the e-journal Internet Archaeology (Aloia *et al*. 2017).

Other ARIADNE products such as research presentations and documents have been made available on SlideShare, which proved to be a very effective dissemination method. By January 2017 in total 91 presentations and 26 documents (i.e. deliverables) have been uploaded on SlideShare. These products received in total 69,270 views; 36,165 over the last twelve months.

2.4.3 TNA study visits and other training

One core objective of ARIADNE has been to support scientific communities in their access to resources and services of research infrastructures/centres, including study visits and training as well as online access to content/data. – This section covers *Part 1: Transnational access (TNA) study visits and other training*.

Key results

- *Transnational access (TNA) study visits:* TNA has been offered by three partners in the form of summer schools or individual visits of one week. 97 researchers from European and other countries benefited from the TNA programme for project-related skills development (well above the 85 initially foreseen in the grant agreement). In addition, a small number of researchers benefited from the programme attending a training event in their own country (which was not eligible for TNA funding).

- The training centred on data-related skills as required for archaeological projects, e.g. data management planning, dataset development, 2D/3D documentation, data mapping and ontologies. The feedback of the researchers on achievements during the TNA for their projects was very positive.
- *Other training provided:* 424 researchers and practitioners participated in 18 tutorials and short courses offered by partners at various events. The number of participants well surpassed the target of 250. The training offer covered topics as in the TNA and introduced participants to online data resources and tools/services developed or enhanced by partners.
- *Development of training programmes:* ARIADNE TNA and other training have inspired related initiatives to plan or rework training offers (e.g. the CIDOC-CRM community). Rework of training offers is also motivated by new tools developed by ARIADNE partners (e.g. vocabulary mapping or 2D/3D tools).

Summary of results

In the Trans-national Access (TNA) programme three ARIADNE competence centres (Athena RC, CNR-ISTI and PIN) offered access for group visits (summer school format) and individual visits of one week. The study visits were offered in the years 2014, 2015 and 2016, with a TNA travel bursary for eligible participants. The TNA programme centred on data-related skills as required for archaeological projects, e.g. data management planning, dataset development, 2D/3D documentation, data mapping and ontologies. The number of applications (136) was below the envisaged 300, a target which on hindsight appears as unrealistic.

Over 100 researchers from European and other countries participated in the TNA programme, 97 with a TNA travel bursary. Of the researchers with TNA funding (97 bursaries) over 70% were young researchers (i.e. postgraduate students and postdoctoral researchers); 50% were female. The participants came from institutions in 23 countries (21 EU member states plus Serbia and Argentina); thirty different nationalities were represented, 20 EU member states plus Argentina, Australia, Brazil, Canada, China, Iceland, Norway, Serbia, Turkey and USA.

The feedback of the researchers on their achievements during the TNA summer schools and individual study visits for their projects was very positive. Also the organisation, logistics and trainers of the TNA offer were appreciated very much. The main potential improvement mentioned by several participants was the wish for longer training courses (more than one week).

In addition to the TNA programme, 424 researchers and practitioners benefited for their research and other tasks (e.g. data management) from 18 tutorials, workshops and short courses at events and partner sites. The number of participants well surpassed the target of 250. The training offer covered topics similar to the TNA and also had a strong focus on novel models, methods and tools offered by project partners. Some workshops also introduced participants to the TNA and data resources accessible online at ARIADNE partners.

ARIADNE TNA and other training offers have inspired related initiatives to plan or rework training efforts. For example, the CIDOC-CRM community is planning a new framework of training for CRM application to cultural heritage data. The current re-organisation of training offers is also motivated by available new tools and services developed by ARIADNE partners. Examples are the tools for knowledge organisation systems (Mapping Memory Manager for CIDOC-CRM/ontology; Vocabulary Mapping Tool for thesauri, taxonomies and other vocabularies) and advanced 2D/3D content tools and web-based services offered by CNR institutes (Visual Media and Landscape Services).

2.4.4 Online access to data resources and services

One core objective of ARIADNE has been to support scientific communities in their access to resources and services of research infrastructures/centres, including study visits and training as well online access to content/data. This section covers *Part 2: Online access to data resources and services*.

Key results

- *Online transnational access services (ADS, Arachne, Fasti Online):* The initial set of ARIADNE online data access services were three services individually provided by Archaeology Data Service (ADS), ARACHNE/iDAI.objects (DAI) and Fasti Online (AIAC). These have been offered in the framework of the ARIADNE TNA programme.
- In the project period 2/2013-3/2016, before the launch of the ARIADNE portal, ARIADNE effects on the number of visitors and page views of the three services were mainly perceived around major conferences. While the service usage slightly increased during the period, effects of ARIADNE could only be discerned when the project was present with sessions, workshops and other activities at major domain events.
- *Provision of datasets for integrated search:* During the project data records of the three initial online TNA services (provided by ADS, DAI and AIAC) and 13 other project partners have been prepared for incorporation and cross-resource search through the ARIADNE data portal. At present 16 data publishers provide 24 datasets, some with many contributors or sub-sets of own resources. 1,905,922 records from providers in different EU countries are now cross-searchable on the ARIADNE data portal.
- *Selected cooperation highlight:* There have been significant advances of individual partners with regard to the accessibility of archaeological data enabled by ARIADNE. An example is the Archaeology Database of the Hungarian National Museum, a new system initially intended for own records. Strong promotion by the museum allowed acquisition of nearly 60,000 records contributed by archaeologists across Hungary. The records are included in the ARIADNE registry/portal.
- *ARIADNE portal access:* Since January 2016 users could cross-search the integrated datasets through the ARIADNE portal (officially launched on the 30th of March 2016 at the CAA conference in Oslo). Until the 5th of January 2017 the portal received over 10,800 visitors in 15,400 sessions with 69,000 page views (the target was 800 visitors/users in the last project year). From July 2016 onwards there has been a significant increase in user activity on the portal.
- *Demographics:* The portal website demographics suggest that there is an international audience for the portal. About 90% of the visitors were from Europe, 10% from other countries (i.e. United States 4.13%, Russia 2.49%).
- *ARIADNE data portal – making a difference to single data services:* Through incorporation in the data portal the volume and coverage of some data categories previously only accessible at individual websites have been increased greatly. In particular this concerns records of archaeo-logical interventions (i.e. site watching briefs and excavation reports).
- *Outlook:* Some additional resources of partners, affiliated institutions and projects are being considered for incorporation in the future, i.e. resources proposed by institutions in cooperation agreements. These would also include resources not yet present in the ARIADNE registry/portal, i.e. metal-detector finds databases, soil datasets or scientific data of ancient metallurgy.

Summary of results

Online transnational access services (ADS, Arachne, Fasti Online)

The initial set of ARIADNE online services, offered in the framework of the TNA programme, were three data services individually provided by Archaeology Data Service (ADS), ARACHNE/iDAI.objects (DAI) and Fasti Online (AIAC). From project start to March 2016, before the official launch of the ARIADNE portal, ARIADNE effects on the number of visitors or page views of the three services were mainly perceived around major conferences. While the service usage slightly increased during the period effects of ARIADNE could only be discerned when the project was present with sessions, workshops and other activities at major domain events (i.e. EAA, CAA, CHNT and others).

ARIADNE data portal – making a difference to single data services

During the project resources of the three initial online TNA service providers and several other partners have been prepared for incorporation in the ARIADNE dataset registry and cross-resource search on the data portal. At present 16 data publishers (ARIADNE partners) provide 24 datasets, some with many contributors or sub-sets of own resources; in total 1,905,922 records have been integrated in the ARIADNE registry and portal.

These are data resources of different types and sizes. At present the largest share of almost 1.7 million records come from sites and monuments inventories/databases (with the largest contribution so far from the UK via ADS). In the other categories of archaeological interventions (142,743 records), fieldwork archives (6924 records), burial databases (343), artefact databases or image collections (52,732 records) and scientific datasets (4835 records) other partners individually or together have larger shares than ADS. The largest part of records of scientific datasets currently comes from the Digital Collaboratory for Cultural Dendrochronology (4635 records).

Through incorporation in the data portal the volume and coverage of some data categories previously only accessible at individual websites have been increased greatly. In particular this concerns records of archaeological interventions (i.e. site watching briefs and excavation reports).

There are examples which represent significant advances of partners with regard to the accessibility of archaeological data enabled by ARIADNE. To mention but one example, the Hungarian National Museum implemented the Archaeology Database, a whole new system initially intended for several hundred own records. Strong promotion by the museum allowed acquisition of nearly 60,000 records (over 891,000 files) contributed by archaeologists across Hungary. The records are included in the ARIADNE registry/portal.

Some additional resources of partners, affiliated institutions and projects are being considered for incorporation in the future, i.e. resources proposed by institutions in cooperation agreements. These would also include resources not yet present in the ARIADNE registry/portal, i.e. metal-detector finds databases, soil datasets or scientific data of ancient metallurgy.

Anticipated future resources would also be much advanced data based on mappings of databases to CIDOC-CRM and recent special extensions such as CRMarchaeo. Several associated partners and ongoing projects aspire to possibly provide data at this advanced level or at least item-level records of various datasets.

Portal access figures

The impact indicators/targets for the ARIADNE portal ("on-line infrastructure services") were: 300 registered users, the majority young researchers, and 800 different anonymous users during the last project year. During the project it was decided that users will not have to register in order to use the data portal. For the use of the data portal in the last project year the figures for the period January 2016 to begin of January 2017 are as follows:

- 10,819 visitors (the target was 800 users in the last project year),
- 15,400 sessions (average duration 3.31 minutes),
- 68,982 page views (on average 4.48 pages viewed/session).

From July 2016 onwards there has been a significant increase in user activity on the portal. The portal website demographics suggest that there is an international audience for the portal. About 90% of the visitors were from Europe, 10% from other countries (i.e. United States 4.13%, Russia 2.49%).

Additional web-based services

A section of the portal presents and links to services and tools that are provided by ARIADNE partners. The section includes web-based services as well as available software tools users can download and install (i.e. the software of the DCCD dendrochronological data repository). The web-based services are the ARIADNE Visual Media and Landscape Services (provided by CNR laboratories), the Vocabulary Matching Tool (USW), and four vocabulary services that can be used for terminology lookup and aligning and linking vocabulary and data resources (UK Heritage Data Vocabularies, Thesaurus RA - Reperti Archeologici, iDAI.gazetteer and iDAI.vocab).

2.4.5 Data interoperability and unified access

The overall goal of ARIADNE activities here was to bring together and integrate, on a European scale, digital resources from different providers for archaeological researchers, practitioners and other users.

In this regard the ARIADNE European-level e-infrastructure is a great achievement for the archaeological sector in Europe. The e-infrastructure provides a common platform where dispersed and currently isolated archaeological data resources can be uniformly described, aggregated, discovered, visualized, accessed and (re-)used. The e-infrastructure services enable tackling a situation of high fragmentation of archaeological data with limited capability for collaborative research across institutional and national as well as disciplinary boundaries.

The core achievements of ARIADNE are the data registry and portal that allow providers to describe their resources based on a common model and users to cross-search the data records and to access relevant data from the pool of shared resources. A strong uptake of data sharing by archaeological institutions and projects could allow discovery of available data from surveys and excavations in different countries, comparative studies of sites and finds, and synthetic research that transcends the spatial and temporal scales of individual projects.

The ARIADNE project has set itself ambitious goals of which one has not yet been achieved. This concerns the “critical mass” of at least 5,000,000 records covering 70% or more of the European countries. All other goals such as enabling data interoperability and unified search and access have been achieved. This section presents and explains, where necessary, the results for the defined indicators/targets of success.

Critical mass of data

The ARIADNE registry and portal have been set up to allow aggregation and cross-searching of archaeological data records from institutions and projects in Europe. Regarding the volume, coverage and type of the records the following indicators/targets have been defined:

- *At least 5,000,000 archaeological records available for access, covering at least 70% of European countries:* The number of records has not been reached. Currently the data portal provides access to 1,905,922 records (38% of the target). Also with regard to the second point the portal

falls short of covering well 20 of the 28 EU Member States or, even, 33 of the 47 of the Council of Europe.

- *100,000 reports available for searching and browsing:* This has been achieved, there are over 150,000 records available, 142,743 records of archaeological intervention reports and others.
- *Rich information provided in terms of metadata and content, i.e. not only text records but endowed with images, 3D etc.:* This also has been achieved. The records have been uniformly described based on the information-rich ARIADNE Catalog Data Model (ACDM), and several resources contain images and 3D models (e.g. Arachne, STARC Repository, 3D-ICONS Ireland and others). With regard to the metadata especially the information on location, cultural periods (date ranges) and subjects merits to be highlighted.

Summary and explanations

The first indicator/target of success obviously has not been fulfilled. To reach 5,000,000 or more records many resources need to be mobilised which are often under the control of national and regional authorities (i.e. national sites and monuments databases and records of archaeological interventions). These cannot be mobilised easily because of existing regulations, fear to expose archaeological site locations (i.e. potential looting), and need to digitise older reports which contain valuable information. A particularly high challenge here pose countries such as Germany (16 Bundesländer) or Spain (17 Autonomous Regions).

Overcome fragmentation

ARIADNE addressed the issue that archaeological datasets often remain isolated, not interoperable and therefore not searchable in an integrated way. The ARIADNE Catalog Data Model (ACDM) allows dataset providers to describe the resources in a central data registry based on a common data model. This enables cross-searching the aggregated records of the resources overcoming their "fragmentation" (i.e. lack of interoperability). The following indicators/targets of success have been defined:

- *100% of datasets integrated via mappings & crosswalks, or other appropriate integrating technologies such as GIS, Linked Data, etc., according to dataset typology:* 100% of datasets integrated based on the ACDM data model.
- *100% of all datasets with a spatial component integrated in a common GIS platform:* All geo-referenced resources are integrated, OpenStreetMap is being used for map-based browsing of information.
- *25% of datasets linked as Linked Open Data (LOD):* 100% of the ACDM based dataset metadata transformed and available as LOD (see below).
- *30% increase in services provided (compared to currently available ones):* ARIADNE provides new and advanced services not provided by others in the sector (see below).

Summary and explanations

The goals have been accomplished. The last two points require some explanation:

Linked Open Data (LOD): LOD are openly accessible data resources that are based on W3C recommended standards, *in primis* the Resource Description Framework (RDF). The ARIADNE Catalog Data Model (ACDM) is based on the W3C Data Catalog Vocabulary (expressed in RDF), adapted for the description of archaeological data resources. The target of 25% of datasets linked as Linked Open Data has been surpassed by transforming all ACDM based dataset metadata to Linked Data. The data is stored in an appropriate database (Virtuoso) and can be queried via a dedicated Linked Data server hosted by ARIADNE partner CNR-ISTI.

Increase in service provision: The ARIADNE registry and portal are unique services newly developed and offered by the project. These services enable integrated, cross-archive search of data resources at the European level, services which were not available before. Other services developed or offered by partners through ARIADNE are also not available from others, at least not with the highly advanced capabilities provided. Examples are the ARIADNE Visual Media and Landscape Services and the Vocabulary Matching Tool. In summary, the availability of new and highly advanced services through ARIADNE has been increased, but a comparison and percentage of increase cannot be given.

Unified access

The indicators/targets for unified access concern the ways users of the ARIADNE portal can search and access data from different resources:

- *100% of datasets accessible through a common interface:* This goal has been accomplished with the ARIADNE portal that provides the common interface to all services and datasets.
- *100% of datasets availing of innovative visualization and semantic annotation tools (where applicable according to dataset type):* Specific interfaces allow for different modes of data search, visualisation and access according to the search paradigm.

Summary and explanations

The goals have been accomplished. The last point requires some explanation:

Semantic annotation tools: These tools do not concern annotation of data on the portal. The portal does not offer tools for end-users to annotate datasets, which data providers perceive as inappropriate or would require very difficult to manage quality control. The tools concern semantic annotation of datasets by the providers (these are addressed in the next section).

Innovative visualization: The portal provides different search and visualisation modes of which some are standard and others not common or highly advanced. Rather standard are: full-text search over the records; tag cloud at entry level, in English, but with multi-lingual results. Among the not common or highly advanced search options are: multi-lingual keyword/subject-based search, including term suggestion; thematically similar records (within individual search results); map-based search & browse, including indication of available records when zooming into the map; geographically similar records (within individual search results); timespan-based search with a visual interface that allows selecting timespans. If content providers employ the services provided by the CNR laboratories (ARIADNE Visual Media and Landscape Services): advanced visualisation and manipulation of accessed objects such as high-resolution images, Reflectance Transformation Images (RTI), 3D artefacts model, 3D terrain and landscape models.

Long-term preservation of records

The indicator/target here is: *Long-term preservation process activated for all datasets*.

Summary and explanations

Long-term preservation mechanisms have been implemented, but for the records (metadata), not the primary data. The ARIADNE e-infrastructure does not provide a central data storage and preservation centre. Primary data are deposited and curated at data archives/repositories of partners or other institutions. The long-term preservation services of the data infrastructure concern the data records (metadata) which are ingested, enriched and included in the ARIADNE data catalogue. Long-term preservation for these records is implemented. This is based on automatically generated PREMIS metadata stored with each data record, including changes of records. The ARIADNE dataset metadata (including the PREMIS metadata) is stored within the e-infrastructure for

long-term preservation. Furthermore, the catalogue has been transformed to Linked Data (RDF) and stored as an RDF dump which provides an additional preservation solution.

2.4.6 Progress in data documentation, linking, processing and visualisation

The overall goal of ARIADNE activities here was to advance digital methods and to demonstrate their innovative capabilities. This summary addressed the methods that have been developed, the next section the demonstration of enabled innovative capabilities.

Key results:

- *CIDOC-CRM extensions:* Project partners developed or improved extensions of the CIDOC Conceptual Reference Model as required for archaeological documentation, i.e. CRMarchaeo for excavations, CRMba for buildings, CRMsci for scientific observations, and others. Furthermore a number of exemplary databases have been mapped to the CIDOC-CRM and relevant extensions. For such mappings a dedicated web-based tool has been developed by FORTH-ICS, the Mapping Memory Manager (3M). The tool is available also for other users and can contribute to a wider uptake of the CIDOC-CRM by archaeological institutions and projects.
- *CHARM models:* The Cultural Heritage Abstract Reference Model (CHARM) is being offered by Project partner CSIC-Incipit for light-weight modelling of documentation of humanities project, including archaeology. In ARIADNE CSIC-Incipit made available a programming library and examples of such models; generated models can be exported in SKOS or OWL formats and used in Linked Data environments.
- *Linked Data methods:* ARIADNE partners developed and employed Linked Data methods for integration of vocabularies and metadata within the project, and prepared the ground for further linking of resources beyond the ARIADNE pool of resources. A major undertaking was the mapping of several thesauri (or term lists) of data providers to concepts of the Art & Architecture Thesaurus (AAT) in RDF/SKOS format. This has been accomplished with tools provided by USW (which are available open source). Also the mapping of databases to the extended CIDOC-CRM (which is expressed in RDFS) generated Linked Data. Furthermore, ARIADNE partners produced and helped others to produce vocabularies in SKOS format. There is an increasing collaboration on, and sharing of, such vocabularies, and ARIADNE has contributed to this development. A section of the ARIADNE portal includes vocabulary mapping tools as well as vocabulary services provided by ARIADNE partners.
- *Data mining techniques:* Pattern mining in Linked Data to support archaeological hypothesis has been trialled by Leiden University together with associated partner VU Amsterdam. The mining was conducted on a graph database of rich metadata records of archaeological fieldwork according to the Dutch SIKB 0102 protocol, with the protocol schema modelled in CIDOC-CRM/CRM-EH, and thesauri of the Archeologisch Basisregister (ABR) for terms used in the records. The results suggest that still richer Linked Data is necessary to derive patterns relevant for archaeologists. Useful results will require fine-grained semantic structures and specific information, ideally including literal and numerical values. Linked Data that fulfils these criteria may allow providing relevant results.
- *Natural language processing techniques:* NLP has been employed for two purposes: extraction, indexing and linking of metadata from archaeological reports ("grey literature"), and identification, extraction and analysis of description of research methods and processes in reports. Both machine learning based and rule-based Named Entity Recognition (NER) and information extraction have been experimented with useful results. The outcomes include:

A machine-learning based application for metadata generation that is being used for the ADS Grey Literature Library, but may be adapted and implemented also by other repositories for English language documents (the code is available). Furthermore ADS provides a NER service API for external users to generate metadata for their data management systems.

Results of rule-based NLP of archaeological reports in Dutch, English and Swedish by USW include improved methods for preparing vocabularies in the different languages for NLP tasks, customized matching and information extraction for archaeological terms, and pipelines for rule-based NLP of reports in the different languages. The pipelines are available on GitHub and run on the widely employed GATE open source NLP platform. The information extracted from reports has been used in a demonstrator of CIDOC-CRM and AAT based semantic integration and cross-searching of information.

NLP-based work on description of research methods and processes in archaeological reports has been carried out by CSIC-Incipit and other partners. The experiments employed a Python NLTK based tool with different methods to identify and extract description of methods and relationships between activities. An archaeological use case, including evaluation by a domain expert, provided encouraging results.

- *ARIADNE Visual Media and Landscape Services:* Laboratories of ARIADNE partner CNR developed own and other open source tools further to provide web-based services for effective publication, visualisation and exploration of high-resolution and complex media types such as reflectance transformation images (RTI) and 3D artefact models and terrain/landscape models. The services are included in ARIADNE's portfolio of freely useable web-based services. The services greatly advance the capability of a wide range of users to effectively generate, publish, visualize and study online high-resolution visual content in novel ways. These include archaeological research projects, digital archives, e-journals, museums and other heritage institutions. The services are already being used by many archaeology and heritage research and dissemination projects.

Summary of results

CIDOC-CRM extension and mappings

The CIDOC-CRM initially has been developed for the documentation and integration of information about artefacts held by museums and other heritage institutions. The conceptual reference model is an ISO standard since 2006 (ISO21127:2006, renewed as ISO21127:2014). Within ARIADNE several CIDOC-CRM extensions have been created or enhanced which together form the ARIADNE Reference Model. This model is intended to allow the accurate documentation of complex entities and relations of archaeological/scientific observations and analysis, data integration and search, involving reasoning over the distributed data and knowledge. The CIDOC-CRM extensions cover documentation and metadata of archaeological excavations (CRMarchaeo), ancient/historic buildings (CRMba), scientific observations and argumentation (CRMsci, CRMinf), spatio-temporal relations (CRMgeo), and digitisation processes (CRMdig).

Archaeological institutions and projects can now model and integrate better various data resources using the CIDOC-CRM with appropriate extensions. This has been exemplified by mappings of a number of representative databases, including databases of fieldwork, finds and monuments, burials and finds such as coins. A new tool, the Mapping Memory Manager (3M) has been developed by ARIADNE partner FORTH-ICS to facilitate the mapping process and the mapping validation. The web-based application eases the mapping of database schemas to the CIDOC-CRM and selected extensions and may contribute to a wider uptake of the CIDOC-CRM by archaeological institutions and projects.

CHARM models

Researchers of project partner CSIC-Incipit offer the Cultural Heritage Abstract Reference Model (CHARM) which can be used for light-weight modelling of documentation of humanities projects, including archaeology. CHARM is expressed in their conceptual modelling language ConML and can be extended to create models which best suit the particular needs of different projects.

In ARIADNE CSIC-Incipit has made available a programming library that can be used with CHARM models, i.e. a modelling engine capable of storing and manipulating ConML models, and examples of such models. The library can be used by software developers who want to create systems for processing archaeological models that are based on CHARM. Models expressed in CHARM can be exported in SKOS or OWL formats and used in Linked Data environments.

Linked Data methods

ARIADNE partners developed and employed Linked Data methods for integration of vocabularies and metadata within the project, and prepared the ground for further linking of resources beyond the ARIADNE pool of resources.

Enabling interoperability and cross-searching of data records from several providers and in different languages based on subjects required mapping of terms of their thesauri (or term lists) to concepts of a common semantic "hub". Therefore partners had to map subject terms they use in data records to the comprehensive Art & Architecture Thesaurus (AAT) that is available in the Linked Data format SKOS.

Over 6400 mappings were conducted, with mappings by individual partners ranging from below 100 to over 1600 terms. Terms from 27 vocabularies employed by 12 project partners have been mapped to the AAT. For example, the Institut National des Recherches Archéologiques Préventives (Inrap) uses many terms of the PACTOLS thesaurus for the subject metadata of their catalogue of archaeological reports (DOLIA). In total 1634 PACTOLS terms have been mapped to the AAT. Most partners used the mapping tools provided by USW (which are available open source).

Furthermore, ARIADNE partners produced and helped others to produce vocabularies in SKOS format. Such work has been carried out before, in parallel to, or within ARIADNE. One example of a parallel development in the UK SENESCHAL project is the set of major British Heritage Data vocabularies which are freely available in SKOS format together with web services and wizards for semantic tagging of data. An example of a vocabulary development supported by ARIADNE is the multi-lingual dendrochronology vocabulary in SKOS format of the Digital Collaboratory for Cultural Dendrochronology (DCCD, hosted by DANS).

There is an increasing collaboration on, and sharing of, Linked Data vocabularies, and ARIADNE has contributed to this development. To give but one further example: ARIADNE partners collected and provided the PeriodO service with a set of 659 periods (Paleolithic to Modern times) for 24 European countries. PeriodO assigns unique resource identifiers (URIs) to period information which allows clear and stable linking of data resources which concern the same period. A new service component has been included in the MoRe aggregator of Athena-DCU to attach PeriodO URIs to period information in records collected for ARIADNE. ARIADNE promotes the use of PeriodO to allow wider interlinking of data based on chronologies in Linked Data initiatives.

A section of the ARIADNE portal includes four services of vocabularies in SKOS format that can be used for terminology lookup and aligning and linking vocabulary and data resources. These are the UK Heritage Data vocabularies (mentioned above), the Thesaurus RA (Reperti Archeologici) of the Italian Central Institute for Catalogue and Documentation (ICCD) for objects coming from archaeological excavations (the SKOS version is being curated by MiBAC-ICCU and PIN VastLab), and

the iDAI.gazetteer and iDAI.vocab of the German Archaeological Institute (DAI). iDAI.vocab comprises of several thesauri of archaeological terminology in different languages.

Data mining techniques

Pattern mining in Linked Data to support archaeological hypothesis has been trialled by Leiden University together with associated partner VU Amsterdam. The work produced interesting results concerning archaeological data. An examination of (few) available sets of archaeological Linked Data found that these consisted largely of flat data structures and descriptive values. These were unlikely to allow pattern mining for hypothesis generation which archaeologists indicated as relevant in a user requirements study of the research group. The study also found that the archaeologists would only consider results of a data mining application if these can be interpreted easily and the methods employed are understandable and trustable.

To have a more complex set of Linked Data the group generated Linked Data of 73 rich metadata records of archaeological fieldwork documentation according to the Dutch SIKB 0102 protocol. The protocol schema was modelled in CIDOC-CRM, including the English Heritage extension (CRM-EH). Furthermore Archeologisch Basisregister (ABR) thesauri of the Dutch Cultural Heritage Agency have been prepared for use in the transformation of SIKB 0102 XML documents to RDF. A graph database has been set up and populated with the RDF data.

The data has been explored with a data mining pipeline developed by the research group (MINoS - MINing on Semantics). Responding to selected archaeologic topics, methods, etc. the pipeline outputs potentially interesting patterns in the Linked Data. Outputs can be (facet) browsed or examined algorithmically using pre-sets. The research results have been encouraging from a technical perspective but still far from useful from an archaeological perspective. Domain experts were surprised by the range of patterns that were discovered, although most described rather trivial facts.

The results confirmed a strong dependence of the usefulness of pattern mining for hypothesis generation on the granularity of knowledge embodied in datasets of Linked Data. For archaeologically relevant results fine-grained semantic data is necessary, which means sufficient complexity of the structural features (i.e. ontologies) and specific information, ideally including literal and numerical values. Linked Data that fulfils these criteria may allow providing relevant results for archaeologists.

Natural language processing techniques

In ARIADNE Natural Language Processing (NLP) has been employed for two purposes: extraction, indexing and linking of metadata from archaeological reports ("grey literature"), and identification, extraction and analysis of description of research methods and processes in reports. Both machine learning based and rule-based Named Entity Recognition (NER) and information extraction have been experimented with useful results.

For machine learning based NER a metadata extraction web application has been developed. The application includes an annotation tool for collecting machine training data, techniques for clustering, labelling and ranking the NER output, and export of selected metadata in a variety of formats. The application has been developed for the ADS Grey Literature Library, but may be adapted and implemented also by other repositories for English language documents (the code is available). Furthermore ADS provides a NER service API for external users to generate metadata for their data management systems.

Project partner USW developed and trialled NER and information extraction from archaeological reports in different languages with their GATE-based OPTIMA semantic annotation system. The published results include improved methods for preparing vocabularies in different languages for

NLP tasks, customized matching and information extraction for archaeological terms, and pipelines for rule-based NLP of reports in English, Dutch and Swedish. The pipelines are available on GitHub and run on the widely employed GATE open source NLP platform. Results of NLP of archaeological reports in the different languages together with extracts from datasets have been included in a demonstrator of CIDOC-CRM and AAT based semantic integration and cross-searching of information.

NLP-based work on description of research methods and processes in archaeological reports has been carried out by ARIADNE partners CSIC-Incipit and AIAC in collaboration with researchers of the Centre de Recherche en Informatique at Université Paris 1 Panthéon-Sorbonne. The experiments employed an automatic tool (TextProcessMiner) that has been developed utilizing Python NLTK and other NLP libraries/components. The tool employs NLP techniques with a focus on the verb semantics for methods/activity mining and rule-based mechanisms for activity relationships detection (based on i.e. sequence, parallelism and mutual exclusion). A demonstration of this NLP approach for the detection, extraction and analysis of method description in archaeological reports, including evaluation by a domain expert, provided encouraging results. The tools of the research prototype are not yet available for general use.

ARIADNE Visual Media and Landscape Services

In ARIADNE's Description of Work no indicators for this field of research & development have been defined. But advanced imaging solutions (i.e. reflectance transformation images) and 3D models of artefacts and terrains are essential in archaeological research documentation and dissemination. A high demand for services that ease the publication and access to such media has been expressed in ARIADNE user workshops and training.

The ARIADNE Visual Media and Landscape Services enable effective generation, publication, visualization and exploration of different media types in high-resolution and different interaction modalities. These services already are being used by many projects:

- The Visual Media Service (CNR-ISTI) for high-resolution images, reflectance transformation images (RTI) and 3D models is available since April 2015. Since then it has been used to process, publish and visualise over 400 3D and other visual media. The service is accessed by several hundred users (data producers and visitors) per month, with increasing figures of access since 2016.
- Launched in spring 2016, the ARIADNE Landscape Services (CNR-ITABC) are being employed by archaeology and heritage research, training and dissemination projects (i.e. virtual museums). Over 300 multi-resolution terrain databases have already been processed and results provided in content galleries on the cloud-based platform.

The services greatly advance the capability of a wide range of users to effectively generate, publish, visualize and study online high-resolution visual content (i.e. 3D models) in novel ways. These include archaeological research projects, digital archives, e-journals, museums and other heritage institutions. For example, digital humanities projects and e-journals increasingly are looking for possibilities to provide media-rich research publications comprising of the papers and underlying data (evidence) presented as high-resolution 3D models or RTI images.

2.4.7 E-research frameworks and demonstrators

The overall goal of ARIADNE activities here was to enable advanced or new digital methods and demonstrate the innovative capabilities. This section covers *Part 2: Innovative capabilities.*

Key results

- *Towards Virtual Research Environments (VREs):* The project has studied the current state of e-research in different fields of archaeological research, perceived difficulties, and requirements for progress towards innovative e-archaeology, possibly based on VREs. Building on the implemented ARIADNE e-infrastructure, one next step could be the creation of VREs, implemented on or related to the data infrastructure and portal. The set of data discovery and access services, data specific web services (e.g. for 3D models of objects and landscapes), and new services and tools for different fields of archaeology could evolve towards advanced VREs.
- *Demonstrated capability to support advanced or new digital methods:* The project achieved significant progress in novel methods of data documentation, linking, processing and visualisation (e.g. extended CRM/ontology, Linked Data, data mining/NLP). Building on this progress the project explored a number of innovative use cases. Twelve application pilots demonstrate innovative capabilities enabled by ARIADNE services/tools, models, vocabularies and datasets (the target was at least 10 demonstrators).

Summary of results

E-archaeology frameworks

The creation of the ARIADNE e-infrastructure and data portal is an essential achievement for the archaeological domain as it provides a common platform where dispersed data resources can be uniformly described, discovered and accessed. One next step could be the creation of Virtual Research Environments (VREs) for e-archaeology, implemented on top of or related to the ARIADNE e-infrastructure.

VREs are web-based research environments which offer generic e-infrastructures services (e.g. data discovery and access) and specific services and tools research communities need for different research tasks and types of data. ARIADNE already offers some e-research services like the visual media and landscape services, which enable effective online publication and exploration of images (e.g. Reflectance Transformation Imaging - RTI) and 3D models of objects and landscapes.

The ARIADNE project has not been charged to develop VREs for researchers in different fields of archaeology, but prepared the ground for such environments based on the e-infrastructure services (i.e. data portal) and additional tools/services for data integration, visualization and (re-)use.

The project has studied the current state of e-archaeology in different fields of archaeological research, perceived difficulties, and requirements for progress towards innovative e-archaeology, possibly based on VREs. The study results suggest that there is much potential for ARIADNE to provide VREs. But the data infrastructure and services will have to take account of the multi-disciplinarity of archaeological research, particularly different data standards and vocabularies that are being used by different research specialities.

Demonstrators of innovative capabilities

Project partners developed demonstrators of innovative capabilities that are enabled by ARIADNE services/tools, models, vocabularies and datasets. 12 demonstrators have been reported, the target was “at least 10”; the report includes a documentation of each demonstrator. The intended users of the innovative capabilities are researchers, data managers and integrators, and developers of novel tools and services. Some of the demonstrators had an experimental character, i.e. data integration based on the extended CIDOC-CRM and different vocabularies. These demonstrated advanced capability to search data resources and identify relevant related information. Others are close to or already productive solutions that are being used by ARIADNE partners and others (i.e. Visual Media and Landscape Services).

2.5 FP7 RI programme impact indicators and results

The project impact evaluation also took account of expected additional and broader impacts of Integrating Activities beyond the indicators of success defined in ARIADNE's Description of Work. These are stated in the relevant FP7 Work Programme for Research Infrastructures (2012). Presenting also these impacts allows highlighting achievements of ARIADNE which are not obvious based on the specific set of indicators employed according to the project's Description of Work.

2.5.1 Structuring impact on the European Research Era (ERA)

The overall goal of ARIADNE activities here was to promote cooperation and connect research communities and resources (data, ICT services) at the European level.

Key results

- ARIADNE built the European-level e-infrastructure for the field of archaeology, which provides direction for and prevents fragmentation of efforts for data mobilization, sharing and integration.
- ARIADNE mobilized a large community of stakeholders around the e-infrastructure. The European Archaeological Council of heads of national bodies charged with the management of the archaeological heritage throughout Europe encourages institutions to share data through ARIADNE.
- ARIADNE is recognized in the ESFRI Roadmap 2016 as the leading European integrator of archaeological research data infrastructures (e.g. national and other data archives in the sector).

Summary of results

ARIADNE has been the catalyst for a *collaborative structuring* of the European Research Area (ERA) in the field of archaeology and related disciplines. The overall goal of this structuring is enabling data sharing of and integrated access to datasets from institutions located in European countries and beyond, promoting a higher level of transnational cooperative research.

ARIADNE has developed a data infrastructure platform (data registry/portal) where currently dispersed and often isolated archaeological data resources can be uniformly described, discovered, visualized and accessed. This European-level e-infrastructure provides direction for and prevents fragmentation of efforts for data mobilization, sharing and integration.

ARIADNE mobilised a large number of stakeholders around the acknowledged e-infrastructure initiative. Recently the ESFRI Roadmap 2016 recognised ARIADNE as the leading European integrator of digital archives/repositories for archaeological research data (ESFRI 2016: 52 and 175). Moreover, the European Archaeological Council encourages institutions to share data through ARIADNE (EAC 2015: 21).

Sharing of data, tools and services fosters mutual understanding and collaboration among the involved archaeological research infrastructures, technological research & development centres, academies of science, research associations and public authorities from different Member States. Capitalising on complementary expertise and capacities leverages the innovation potential of the shared e-infrastructure and data resources for the institutions and user communities involved.

2.5.2 Coordinated evolution of research e-infrastructures

The overall goal of ARIADNE activities here was to contribute to the coordinated development/ evolution, synergies and integration of e-infrastructures in the target area of archaeology and related fields of the humanities and heritage sciences.

Key results

- ARIADNE contributed substantially to the clustering, coordination and knowledge exchange among the relevant e-infrastructure initiatives in the field of humanities and heritage sciences.
- ARIADNE collaborates with many actors to evolve in a coordinated way e-infrastructure based research in the multi-disciplinary field of archaeology, i.e. actors in the areas of prehistory, ancient history, epigraphy, environmental archaeology, dendrochronology, cultural periods, and others.

Summary of results

ARIADNE has contributed substantially to the *coordinated evolution* of e-infrastructures and digital resources for humanities and heritage sciences, including archaeology. Coordination activities included clustering and knowledge exchange with e-infrastructure initiatives such as CENDARI, CLARIN, DARIAH, Europeana, IPERION-CH, PARTHENOS and the new ESFRI initiative E-RIHS.

The partnership of ARIADNE, DARIAH and PARTHENOS merits to be highlighted with regard to common policies and interoperability of e-infrastructures for the humanities and heritage sciences. The collaboration with Europeana Research, which builds on the massive cultural heritage content of Europeana, may not only benefit researchers but also foster interest of teachers, students and the wider public in archaeology, classical studies and related disciplines.

The primary focus however is enabling e-infrastructures support ICT-enhanced research in the multi-disciplinary field of archaeological research. In this regard the collaboration of ARIADNE with institutions and projects in specific areas are of vital importance. To mention but a view: with regard to prehistory (CENIEH, Spain; DGUF, Germany), ancient history (Pelagios), dendrochronology (DCCD), cultural chronologies (PeriodO), environmental archaeology (SEAD, Sweden), and others. Coordination and targeted collaboration fosters synergies among projects, sharing of resources, cross-fertilisation and interdisciplinary approaches.

2.5.3 Improved development, access/use and sustainable operation of RIs

The overall goal of ARIADNE activities here was to support optimal development, operation and use of integrated data archives, ensuring that researchers and other users have reliable and efficient access to data they require for research and other purposes.

Key results

- ARIADNE has developed integrated access to existing national-level and other archaeological data archives in Europe, enabling use of data from different European countries (e.g. for comparative studies and synthesis).
- The project has also investigated the requirements for sustainable operation of data archives (e.g. mandates, certification, cost structures), and partners have shared widely best practices in the operation of archives.
- ARIADNE has promoted new initiatives for national-level data archives and e-infrastructures for the archaeological research community in several European countries, and fostered knowledge transfer between established data centres and new initiatives.
- ARIADNE data archives and other European institutions have submitted an EU COST Action proposal aimed to expand the sharing of expertise in digital archiving ("Saving European Archaeology from the Digital Dark Age - SEADDA", submitted 1/12/2016).

Summary of results

ARIADNE has developed integrated access to existing national-level and other archaeological data archives in Europe, enabling discovery and (re-)use of research data from different countries for comparative and other studies. Indeed, the project has put the sharing of data through digital archives and integrating e-infrastructure on the agenda of the archaeological research community in Europe.

ARIADNE has investigated the conditions for sustainable operation of data archives (e.g. cost structure, centralised service, mandate), and partners have widely shared best practices in their development, management and use, directly as well as through online guides to good practice.

Exchange, discussion and dissemination of consolidated knowledge in digital archiving of archaeological and other humanities data has been enabled in 13 dedicated events, 11 organised by ARIADNE digital archivists and researchers. These events involved leading institutions and projects in the field and have been attended by over 500 people.

ARIADNE also promoted new initiatives for national-level data archives and e-infrastructures for the archaeological research community in several European countries (i.e. Austria, Hungary, Ireland and Slovenia). Furthermore the project fostered knowledge transfer for state-of-the-art archives between established and new initiatives.

The ARIADNE data archives and other institutions have submitted an EU COST Action proposal "Saving European Archaeology from the Digital Dark Age - SEADDA" (1/12/2016), aimed to collect, consolidate and transfer best practices in archiving, dissemination and re-use of archaeological data.

Overall ARIADNE has increased the maturity of the discipline with regard to research infrastructures (digital archives and integrating e-infrastructure) and the participation of institutions in the development and sharing of data resources

2.5.4 Cross-disciplinary fertilisation

The overall goal of ARIADNE activities here was to enable fertilisation between different fields of research, e.g. sharing of data, conceptual understanding and integration, collaboration on novel tools/services.

Key results

- ARIADNE provides data services relevant to all scholarly/scientific domains involved in archaeological research; sharing and linking through ARIADNE various data can stimulate cross-disciplinary fertilisation among researchers of the different domains.
- ARIADNE promoted cross-fertilisation with regard to the conceptual understanding of different fields of research (e.g. use and extension of the CIDOC-CRM ontology), and collaboration of scholars and technologists on new software tools and services.

Summary of results

Archaeology is a multi-disciplinary discipline that spans several fields of the humanities (e.g. history of arts and architecture, classical studies, historical archaeology, ethnography and others) as well as has close ties with the natural sciences (e.g. projects that use archaeometrical, biological and environmental research methods).

ARIADNE provides data services relevant to all scholarly/scientific domains involved in archaeological research. Sharing and linking through ARIADNE of data sets which contain various data can stimulate cross-disciplinary fertilisation among researchers of different domains both within and beyond the

humanities. ARIADNE researchers also have explored the potential of virtual research environments (VREs) for archaeological projects in view of enabling domain and cross-domain integrative research.

Cross-fertilisation has been promoted with regard to the conceptual understanding of different fields of research through the application of knowledge organization systems (thesauri, ontologies) for the linking and integration of data resources. Especially the extended CIDOC-CRM (ARIADNE Reference Model) has the potential to stimulate cross-fertilisation among different fields of research.

ARIADNE also fostered cross-fertilisation between scholars and developers of software tools for research purposes. This has been experienced in the trans-national study visits and courses where scholars learned how to apply various tools, and software developers learned about the requirements of the scholars' projects.

The evaluation has also considered the potential of the ARIADNE data infrastructure and services for promoting interest in questions of archaeology and heritage by educators, students and the wider public, maybe stimulating study work and visits to archaeological sites and cultural heritage museums. Access to archaeological "open data" may foster a broader engagement of citizens in digital archaeology.

However, it has been concluded that it is too early to evaluate if ARIADNE allows non-experts a deeper involvement in (online) "public archaeology" or "community archaeology" projects. A future evaluation of the ARIADNE data infrastructure and services, after some years of regular operation, could look for cases where they have been used in such projects and in citizens' own investigations.

2.5.5 Sharing of knowledge & technologies

One core objective of ARIADNE was to share new knowledge and technical solutions (tools/services) across fields of research, with related public sector bodies and businesses, and enable innovation beyond the research sector. This section covers *Part 1: Sharing of knowledge & technologies.*

Key results

- ARIADNE partners shared new knowledge and advanced or new models, methods, tools and services widely across relevant fields of research, including the multi-disciplinary field of archaeology, cultural heritage and humanities research, and heritage sciences.
- The project outcomes are available also for public sector organisations and businesses that are active in these fields (e.g. cultural heritage administration/management, contract archaeologists and consultancies) and others for whom the advanced or new knowledge and technical solutions are relevant.

Summary of results

ARIADNE has shared new knowledge and results of technological development widely across relevant related fields of research. The knowledge and technology transfer includes sharing of models, tools/techniques and services, presentations, tutorials and short courses for tool/service users, good practice guides, and publications on use cases and research results.

Know-how and technologies for data archiving and publication

In many events and other dissemination activities ARIADNE has put the need for data sharing through state-of-the-art archives and integrating e-infrastructure on the agenda of the research community. Project partners have shared widely good practices in the development and operation of digital archives. In particular, ARIADNE has fostered knowledge transfer between established data

archives/centres and initiatives for centres in other European countries, so that new entries may "leapfrog" to a state-of-the-art solution by learning from acknowledged benchmarks.

In addition to this knowledge transfer ARIADNE partners have contributed to the development and sharing of data archiving and publication solutions. Examples are experiences reported on the use of the ARCHES platform for cultural heritage inventory and management (developed by Getty Conservation Institute and World Monuments Fund); mirror hosting, back-up and enhancements of the Open Context data publication platform by the German Archaeological Institute; and open source sharing of the repository software of the Digital Collaboratory for Cultural Dendrochronology (DCCD) by DANS.

Know-how and technologies for integrating e-infrastructure and services

Data infrastructures and services employ various standards and technologies, some of which have been adapted and/or improved by the project. ARIADNE provides an example for the adaptation and use of the W3C recommended Data Catalog Vocabulary – DCAT for the description of datasets of a domain of research; employs the MoRe (Metadata & Object Repository) aggregator which is provided by ARIADNE partner Athena-DCU as a Cloud-based service; and shares tools that enhance data interoperability, e.g. the Vocabulary Matching Tool and the Mapping Memory Manager (3M) which facilitates the mapping of databases to the extended CIDOC-CRM.

Natural Language Processing (NLP)

NLP is a well-established field of research and development with numerous solutions and productive applications. ARIADNE work in this field employed different frameworks such as GATE (General Architecture for Text Engineering) and Python NLTK (Natural Language Toolkit), and investigated various methods for improving NLP tasks specifically for archaeology and cultural heritage content. A major goal in this area has been making reports of archaeological fieldwork, specialist analysis and other "grey literature" better accessible and useful through NLP based metadata extraction. Arguably the greatest advance has been achieved in the investigation of what can be achieved by, and what still needs to be improved for, employing archaeological terminologies in different languages for this purpose.

Visual Media and Landscape Services

Project partners have developed web-based services for visual media (high-resolution images, Reflectance Transformation Imaging and 3D artefact models) and large 3D terrain and landscape models. These services are included in the ARIADNE portfolio of web-based services. Employing such services/tools in research projects, for content deposited in digital archives and/or published in e-journals greatly advances researchers' capability to publish, access, visualize and study archaeological and other cultural heritage objects online.

ARIADNE's focus has been on specific needs and requirements of archaeology and cultural heritage. Therefore most of the models, tools/techniques and services have been specifically developed or customised for users of this sector, but some may also be relevant to other domains.

2.5.6 Potential for industrial innovation

One core objective of ARIADNE was to share new knowledge and technical solutions (tools/services) across fields of research, with related public sector bodies and businesses, and enable innovation beyond the research sector. This section covers *Part 2: Potential for industrial innovation*.

Key results

- Innovation in the archaeological "industry" seems feasible mainly through enhanced access to shared knowledge, e.g. fieldwork reports of contract archaeologists and academic research and synthesis.
- Access to more and richer data/information about archaeological sites, monuments and objects can benefit also heritage-led regional development and cultural heritage communication, e.g. urban regeneration projects and cultural heritage tourism.
- There is low potential for ICT businesses to provide e-infrastructure and services (e.g. data archives) for archaeological research.

Summary of results

Industrial innovation in archaeology

With regard to businesses in these fields the notion of "industrial innovation" as promoted by the Research Infrastructures programme can hardly be applied. The notion is informed by large physical research infrastructures where innovation may result from industrial providers being challenged to come up with novel instrumentation, joint R&D projects with the RI, or the use of experimental facilities. Industry in archaeology means contract archaeologists and consultants who provide fieldwork services in so called developer-led or preventive archaeology.

One area where both private sector and academic archaeologists can benefit is the sharing of the outcomes of their work through digital archives. Contract archaeologists produce many fieldwork reports that are important for progress in archaeological knowledge. If such reports can be made better accessible together with academic research and synthesis, all actors can benefit from a common resource, e.g. for preparing fieldwork, excavations and conservation of work.

Access to more and richer data and information about archaeological sites, monuments and objects can also benefit heritage-led regional development projects, e.g. in areas such as urban regeneration and cultural heritage tourism. Special ARIADNE services such as the Visual Media Services may be used in the online presentation of archaeological and other cultural heritage objects and sites.

Industry involvement in data infrastructure services

With regard to the participation of industrial actors in the development of e-infrastructures the EPIRIA evaluation of the FP7 Research Infrastructure programme has shown that their involvement in Integrating Activities has been rather low. ARIADNE followed the general pattern of Integrating Activities in that research organisations rather than ICT businesses have been entrusted with the development of the technical solutions and services. The main reason is that the involved research organisations and digital archives have a track record in implementing data services for the cultural heritage sector.

Data infrastructure and services build on a well-established set of technical approaches and open standards and software so that ICT businesses may try becoming service providers. However we assume that running a data infrastructure and services specifically for archaeological research and dissemination (or other fields of research) does not represent a business case for private sector companies.

Data archives present a similar situation based on a division of work in the academic publishing sector. Most research publishers do not see data management and preservation as part of their core business. As open data mandates of research funders have become more widespread, most publishers recommend dedicated research data archives, while few have implemented an own repository for data underpinning publications in their journals. Data repositories which are operated

by commercial actors are rare: Examples are Figshare (run by Macmillan Publishers' Digital Science) and Mendeley Data (Elsevier), for the latter DANS provides long-term data archiving.

2.6 Overall results, conclusions and recommendations

We briefly recapitulate the objectives of the ARIADNE project, summarise the overall results and conclusions of the project evaluation, and give recommendations for ARIADNE and other stakeholders with a focus on potential further advances.

ARIADNE objectives

The overall objectives of the ARIADNE project have been to mobilise many stakeholders in the sharing and (re-)use of archaeological data, and to implement e-infrastructure services that allow institutions and projects to make valuable data available to the wider community. ARIADNE thus aimed to accelerate archaeology in Europe from a starting to an advanced community in terms of data sharing capacity and integrated access to research resources. The objectives can be summarised as promoting innovation in ICT-enhanced archaeology based on sharing of data and other resources through the ARIADNE e-infrastructure (i.e. datasets, vocabularies, tools/services).

Overall results

The evaluation shows that ARIADNE achieved *very good results* in almost all evaluation dimensions. In particular, the project

- Accomplished its goal to implement an e-infrastructure and services for cross-searching repositories/databases of archaeological data and seed it with representative datasets of project partners;
- Achieved a large "footprint" in the sector with regard to numbers of institutions and researchers that have been reached and involved, including potential providers of additional datasets;
- Increased data interoperability based on a common model and enhanced vocabularies (i.e. ARIADNE Catalogue Data Model, extended CIDOC-CRM, vocabulary mapping tools);
- Implemented a European-level data portal providing advanced search capability with regard to archaeological subjects, locations and timespans (cultural periods);
- Made available additional high value services (i.e. 3D artefact and landscape services), and demonstrated advanced capability in making data better accessible and useful (i.e. metadata extraction from archaeological "grey literature", CIDOC-CRM based data integration).

At the core of the ARIADNE project has been the building of a European-level platform where dispersed archaeological data resources can be registered, shared, discovered and accessed. Such a platform did not exist before and its implementation arguably is the project's key innovation for the archaeological community in Europe (and beyond).

Wide reach and involvement of stakeholders

The wide reach and large direct involvement of individual researchers, practitioners, students and others (about 10,500) in activities such as needs & requirements surveys, transnational access (TNA) and other trainings, and sessions and individual presentations at sector conferences, workshops merits to be highlighted.

The conservative estimate of 10,500 participants is 30 times larger than the membership of the Computer Applications and Quantitative Methods in Archaeology (CAA) organisation/conference (350), 5 times larger than the membership of the European Association of Archaeologists (2000+),

and about 32% of the number of archaeologists working in Europe (33,000), estimated by the Discovering the Archaeologists of Europe project.

Moreover the number of involved European archaeology and cultural heritage institutions (65 of 26 countries) and institutions outside Europe and international initiatives (19) appears as exceptional. The institutions have been involved in various ways, i.e. cooperation agreements, liaisons and joint activities on an informal basis; a number of agreements include contribution of datasets, given required funds are available.

Substantial results on several fronts

The project achieved substantial results on several fronts including, but not limited to, *increase* in

- Awareness of the importance of data archiving and access, including the need of appropriate archives for archaeological data,
- Exchange and transfer of knowledge in data archiving solutions and practices, possibly allowing communities that lack an appropriate archaeological data archive to "leapfrog" to an optimal solution;
- Skills development for making new as well as legacy datasets more useful and better accessible (i.e. TNA study visits to competence centres and other training);
- Mobilisation of institutions in the sharing of archaeological datasets (i.e. cooperation agreements),
- Data sharing capacity, through the ARIADNE data infrastructure,
- Services to publish, discover, visualise, access and use data for research and other purposes (i.e. ARIADNE data registry & portal, visual media and landscape services),
- Interoperability of data (i.e. ARIADNE Catalog Data Model, extended CIDOC-CRM and vocabulary mappings),
- Coordinated development of e-infrastructure initiatives in the fields of digital humanities, archaeology and heritage sciences.

High recognition at all levels

The reported advances on several fronts, achieved or enabled by the ARIADNE initiative, have been recognised by participants of trainings and professional development, research directors and national institutes, and the core institutions of both the archaeological sector and the area of research infrastructures:

- The European Archaeological Council strongly encourages institutions to participate in and share data through ARIADNE.
- The European Strategy Forum on Research Infrastructures (ESFRI Roadmap 2016) recognises ARIADNE as the core European integrator of archaeological research resources.
- Complementing the high-level recognition, testimonials of archaeology and cultural heritage institutions and researchers confirm ARIADNE's impact both at the national level, where access to data has been greatly improved in some cases, and at the European level, through the data registry/portal which allows cross-searching the improved and integrated data. Furthermore, participants in the Transnational Access (TNA) programme acknowledged the high value of the training provided for their own or institutional projects.

Thus the ARIADNE project achieved more than a large "footprint" in the sector – the project achievements are being recognised at all levels.

Conclusions and recommendations

ARIADNE has been an EU-funded Integrating Activity aimed at overcoming a situation of dispersed and isolated archaeological data resources. The project has achieved essential results that allow data sharing, interoperability and accessibility for research across institutional and national as well as disciplinary boundaries.

The evaluation results demonstrate that the ARIADNE project has a *strong* impact in the field of archaeological research and data management in Europe, and that this may become a *lasting* impact. The results are encouraging and a solid basis for taking appropriate next steps.

The evaluation concludes that based on the project results there is a *high potential for further advances* based on sharing of data and other resources through the ARIADNE e-infrastructure.

The period of EU support for the ARIADNE project ended. However the not-for-profit ARIADNE Association has been set up to enable continued operation of the current dataset registry and access portal, further community networking and offering training for potential data providers.

To realise the full potential of the implemented data infrastructure and portal for the archaeological research community, it is necessary to keep the momentum, incorporate additional datasets, and ensure the sustainability of the e-infrastructure operation. Therefore a number of recommendations are given for stakeholders in the ARIADNE initiative:

Institutional stakeholders

ARIADNE provides a common platform for archaeological data publication, discovery and access. The platform is a community asset which, however, requires sustained efforts for maintenance and extension. Therefore all institutional stakeholders in accessible archaeological data, i.e. professional associations, research institutes and funding agencies, should consider

- Utilizing the platform for own and community wide purposes (i.e. open sharing of data as increasingly demanded by funding bodies);
- Supporting the platform by making available resources and/or mobilising data providers (i.e. datasets of institutions from countries not yet present on the ARIADNE portal);
- Delegation of a representative to the ARIADNE Association to express and promote common interests in the continuation of the e-infrastructure and other activities (i.e. open data advocacy, training and professional development).

ARIADNE initiative

For the ARIADNE initiative, represented by the ARIADNE Association, the following recommendations can be given:

- *Training offer:* Focus on providing training for potential providers of new datasets (i.e. curators of institutional legacy databases and major new projects); align with the knowledge transfer for new archaeological data archives (i.e. the SEADDA initiative).
- *Maintenance of the current services:* Keep the current services running, including basic maintenance and updates (if required), until new funding for extension of datasets and services are acquired, for example in a follow-up project.
- *Incorporation of new datasets:* Attempt to incorporate new datasets based on specific arrangements and/or according to the availability of own or external funds. A number of institutions have expressed their interest to use the data registry and portal for publishing datasets.

- *Project based sustainability:* Substantial extension of resources (datasets, tools/services) and continued sustainability will require a series of funded projects or dedicated national or international funding commitments.
- *Long-term sustainability:* An approach for long-term sustainability of the e-infrastructure and services could be a foundation, endowed with and/or renewed significant funding. Another option could be that an ESFRI Research Infrastructure of the humanities and heritage sciences sector (DARIAH, E-RIHS) takes up the e-infrastructure and adapts and utilizes it to support research communities, including archaeological researchers.

These recommendations are generally in line with the ARIADNE sustainability plan that is included in the ARIADNE Final Innovation Agenda and Action Plan (D2.4, November 2016).

3 Framework of the impact evaluation

3.1 General framework

The framework of the impact evaluation comprises of the different dimensions in which the project intended to make a difference, the various types of impacts envisaged, and the defined indicators (evidence) for these impacts. The framework is largely determined by the fact that ARIADNE has been funded as an Integrating Activity project under the European Union's Seventh Framework Programme for Research and Technological Development (FP7), specifically the Research Infrastructures programme (2012). The Integrating Activity scheme prescribes that projects have to carry out a defined set of activities: Networking activities, Trans-national access and/or service activities, and Joint research activities. The second core element for the impact evaluation framework is that ARIADNE set out to build an e-infrastructure that integrates and provides access to archaeological datasets.

In order to allow a comparative approach the ARIADNE impact evaluation looked for an established framework for the evaluation of the impact of Integrating Activities for networks of research infrastructures. But such a framework does not exist, despite the fact that across all disciplines about 90 such projects have been funded under FP7[9]. The reason appears to be that the significant differences of the projects with regard to disciplines, types of research infrastructures and user communities do not allow the application of a common evaluation framework. A similar situation exists with regard to a comparative analysis of impacts of different e-infrastructure projects (see *Section 3.3* and *Annex B*).

Therefore the conclusion was that the ARIADNE project must be evaluated primarily according to its scope and expected impacts as defined in the Description of Work (Grant Agreement). In addition the evaluation takes account of a number of expected broader impacts of Integrating Activities stated in the relevant FP7 Work Programme for Research Infrastructures (2012). Indeed, addressing also these impacts allows highlighting achievements of ARIADNE which are not obvious based on the specific set of indicators employed according to the project's Description of Work.

The sections that follow describe the Integrating Activity scheme and the e-infrastructure component of ARIADNE. Furthermore the impact evaluation task, its overall focus and time horizon, and the different impact dimensions and indicators are addressed.

3.2 ARIADNE as an Integrating Activity

ARIADNE is an Integrating Activity, funded under the European Union's Seventh Framework Programme for Research and Technological Development (FP7), Work Programme 2012 for Research Infrastructures. The ARIADNE project proposal responded to the topic INFRA-2012-1.1.3, "Research infrastructures for archaeological datasets and related technologies".

According to the FP7 Work Programme 2012 for Research Infrastructures[10], "*The aim of Integrating Activities is to bring together and integrate, on a European scale, key research infrastructures, in order to promote their coordinated use and development. This will ensure that European researchers*

[9] European Commission, DG Research & Innovation, Infrastructures: FP7 funded I3 projects (Networks of RIs funded as Integrating Activity projects), https://ec.europa.eu/research/infrastructures/index_en.cfm?pg=ri_projects_fp7

[10] Source of the quotes that follow: FP7 Work Programme 2012. Capacities: Part 1: Research Infrastructures. European Commission C(2011)5023 of 19 July 2011, pp. 8-10, https://ec.europa.eu/research/infrastructures/pdf/wp2012_research_infrastructures.pdf

have a wider and more efficient access to the high performing research infrastructures they require to conduct their research, irrespective of the location of the infrastructures".

As stated in the Work Programme, an Integrating Activity *"shall combine, in a closely co-ordinated manner, following the Integrated Infrastructures Initiatives (I3) model:*

- *Networking activities,* to foster a culture of co-operation between research infrastructures and scientific communities and help developing a more efficient and attractive European Research Area;
- *Transnational access and/or service activities,* to support scientific communities in their access to the identified research infrastructures;
- *Joint research activities,* to improve, in quality and/or quantity, the services provided by the infrastructures.

All three categories of activities are mandatory as synergistic effects are expected from these different components."

The ARIADNE project has been set up according to the Integrated Infrastructures Initiatives (I3) model, hence combines Networking activities, Trans-national access and/or service activities, and Joint research activities. The evaluation of the impact of the ARIADNE project focuses on the impacts of the different I3 activities taking account also of perceived synergistic effects.

3.3 ARIADNE as an e-infrastructure initiative

One major objective of ARIADNE has been to bring together and integrate research infrastructures in the field of archaeological research so that researchers (archaeologists and others) have a wider and more efficient access to shared resources and services.

Under the term Research Infrastructure (RI) very different facilities and services are subsumed. The European Strategy Forum on Research Infrastructures (ESFRI)[11] distinguishes between "single-site", "distributed" and "virtual" RIs (ESFRI 2006: 16). A single-site RI is a major facility at which research is conducted, for example, a molecular biology laboratory or a synchrotron, and a distributed RI is a network organisation of such facilities based on common principles of service provision. A virtual RI is an e-infrastructure that provides digital services such as connectivity, authentication/authorisation, data search and access, use of computing resources[12].

ARIADNE has created a virtual infrastructure that provides data registration, discovery, access and other services on top of distributed digital archaeological archives/repositories. These archives/ repositories are infrastructures that are integrated by the ARIADNE data infrastructure and services which are accessible through a common data portal. It is important to note that this e-infrastructure did not exist before but has been developed by ARIADNE; it represents the project's core innovation in the field of archaeological research and data management. Therefore the impact of ARIADNE as an e-infrastructure initiative must be evaluated with regard to the realised data infrastructure and services (e.g. integration of data resources, novel services, etc.) and the potential they provide for further innovation in the domain of archaeological research.

[11] ESFRI - European Strategy Forum on Research Infrastructures, http://ec.europa.eu/research/esfri/

[12] The Research Infrastructures Observatory, http://observatory.rich2020.eu, provides information about 341 Research Infrastructures and RI support projects that have been funded by the European Commission through the 7th Framework Programme for Research; 138 of the entries are e-Infrastructure projects.

For the impact evaluation it is important to distinguish ARIADNE's data- and domain-centred e-infrastructure from other e-infrastructures and services. The table below presents the different types of e-infrastructures.

Type	*Brief description*	*Examples*
High Performance Computing (HPC)	Advanced computing services based on supercomputers for scientific and engineering applications	PRACE (provides access to six HPC systems)[13]
Distributed Computing Infrastructure (DCI)	DCIs provide a gateway to Grid/Cloud-based computing resources and tools (e.g. virtual machines), which may be used stand-alone or as part of a VRE	EGI.eu (coordinates a pan-European platform of DCIs)[14]
Virtual Research Environments (VREs)	A combination of e-research tools and services as required by a research community; may be implemented on data or computing e-infrastructure	The set of ARIADNE general & specific services (e.g. visual media & landscape services) may evolve into a VRE[15]
Domain Data Infra-structure & Services	Data registration, cross-archive search, access and other services for a specific domain	ARIADNE Other examples: CENDARI[16], IPERION-CH[17]
Domain-based Data Archives/Repositories	Services for curation and long-term access to research data of a specific domain	Archaeology Data Service, E-Depot for Dutch Archaeology and other ARIADNE archives Other examples: GenBank[18], PANGAEA[19]
Generic e-Infrastructure & Services	Generic services such as data identifiers, storage and replication, metadata solutions, authentication/ authorization and others	DataCite[20], EUDAT[21], OpenAIRE[22]
Research and Education Networks	Internet connectivity, data transfer and communication services	GÉANT[23] and national Research and Education Networks

[13] PRACE - Partnership for Advanced Computing in Europe, http://www.prace-project.eu

[14] EGI.eu - International Grid & Cloud Infrastructure for Research, http://www.egi.eu

[15] Examples of VRE projects are BioVel (FP7; ecology), https://www.biovel.eu; ViBRANT (FP7; biodiversity/ taxonomy), http://vbrant.eu; BlueBRIDGE (H2020, marine sciences), http://www.bluebridge-vres.eu; EVER-EST (H2020; earth sciences), http://www.ever-est.eu

[16] CENDARI - Collaborative European Digital Archive Infrastructure, http://www.cendari.eu

[17] IPERION-CH - Integrated Platform for the European Research Infrastructure on Cultural Heritage, http://www.iperionch.eu

[18] GenBank, http://www.ncbi.nlm.nih.gov/genbank/ (includes over 11,000 records of ancient DNA of humans, animals, plants, bacteria, etc.)

[19] PANGAEA – Data Publisher for Earth & Environmental Science, http://www.pangaea.de (includes over 3200 datasets related to "archaeology")

[20] DataCite, https://www.datacite.org

[21] EUDAT - European Data Infrastructure, http://www.eudat.eu

[22] OpenAIRE - Open Access Infrastructure for Research in Europe, http://www.openaire.eu

Taking account of essential differences between e-infrastructures

Impact evaluation must take account of the essential differences between the existing types of e-infrastructure. They are not comparable but are positioned in different layers of the e-infrastructure ecology (see table above).

The general basis is networks that provide Internet connectivity and data transfer and communication services (i.e. Research and Education Networks). Next there are the generic services for data identification, management, search and access, e.g. EUDAT has developed a number of such services which can be employed by e-infrastructures of different disciplines. We also include here OpenAIRE, mainly because this e-infrastructure is meant to support projects of all disciplines. OpenAIRE assists the EU policies on open access publications and data, allowing search for research outputs and information about EU funded projects, organisations and researchers.

The ARIADNE initiative is positioned in the domain-focused layer of e-infrastructures. ARIADNE builds on data archives/repositories that specialise in the curation of archaeological and other cultural heritage data, and provides integrating services that allow cross-archive search, access and other services. Also Virtual Research Environments (VREs) typically support researchers in one or a group of related domains of research. VREs implement a combination of e-research tools and services as required by a research community. ARIADNE's set of general services (e.g. data search and access) and specific services for different types of data (e.g. visual media, landscape and other services) may evolve into such a VRE for researchers in archaeology and other heritage science disciplines.

Distributed Computing Infrastructure (DCI) provides access to Grid/Cloud-based computing resources and tools through a Science Gateway. A Gateway uses generic DCI services such as authentication/authorization and supports the user community in the use of their applications (e.g. virtual machines) and available computing resources. User groups can share applications and data and, thereby, form a virtual research community. Finally High Performance Computing (HPC) infrastructure provides advanced computing services based on supercomputers that are accessible remotely as part of Grid-based e-infrastructure or other dedicated high-throughput connections.

For the evaluation of the impacts of these e-infrastructures it is important to consider their different functions and user communities. A comparison of the impact of ARIADNE's e-infrastructure with those of other Integrating Activities might be conducted if they develop the same type of data infrastructure and services, those which integrate and provide access to *domain-based* data archives/repositories or databases. A comparison with other e-infrastructures would be inappropriate, e.g. between the ARIADNE data infrastructure and a Grid-based Distributed Computing Infrastructure. The same applies to comparisons between other types of e-infrastructures, for example, Research and Education Networks (providing connectivity and data transfer services) and Grid-based DCIs and HPC centres (cf. Purcell 2013).

Because of the differences between the e-infrastructures impact evaluation frameworks developed by projects such as E-nventory and IMPACT are relevant mainly at the aggregate level. E-nventory developed a platform for monitoring investments, development, usage and impacts of networking, grid and high-performance computing e-infrastructures[24]. IMPACT aimed to provide the European Commission with a conceptual framework for monitoring the impacts of all types of (research) e-infrastructure projects funded under the e-Infrastructures programme. The proposed indicators were intended to evaluate at the aggregate level their contribution to EU policy goals (Digital Agenda, Innovation Union), the European Research Area (ERA) science and innovation system, and other

[23] GÉANT - European research and education networking collaboration, http://www.geant.net

[24] E·nventory - The European e-Infrastructures Observatory, http://www.enventory.eu

impacts (Fraunhofer ISI & ZEW 2012; the IMPACT indicators are addressed in greater detail in *Annex B*, *Section 7.3*).

3.4 Impact evaluation task, focus and horizon

This section describes the impact evaluation task as defined in the Description of Work (Grant Agreement), its overall focus on innovations achieved or enabled by project outcomes in the field of archaeological research (*in primis* the ARIADNE e-infrastructure, but also other outcomes), and the impact phase/horizon covered, which is the implementation rather than the operational phase of the data infrastructure and services.

Impact evaluation task

For the ARIADNE impact evaluation in the first place the impacts defined in the Description of Work (Grant Agreement) are relevant. According to the project's Description of Work (DoW), Task 2.5 Impact Evaluation *"analyses the impact of ARIADNE in terms of overall innovation; building the user community; liaisons with stakeholders and with related initiatives; integrating datasets; enabling new and improved services; and productive innovative tools, services and methodologies"* (ARIADNE DoW, Part A: 9).

Furthermore it is stated that the Final Report on Project Impact (D2.5) *"evaluates the project impact according to the indicators and methods described in section 3. In particular it will assess the innovation dimension of the project based on the achieved mobilization and usage of the research infrastructure data and services, effects on the ERA archaeological community and research practices"* (ARIADNE DoW, Part A: 11).

For the evaluation of the impacts of ARIADNE a set of indicators of success has been defined for the different project activities and included in the Description of Work (Part B, section 3, pp. 55-56); this set has been employed for the impact evaluation. Furthermore the evaluation takes account of a number of expected broader impacts of Integrating Activities as stated in the Work Programme 2012 for Research Infrastructures. The two sets of impact indicators are included in *Annex A* and summarised below.

Impact evaluation focus

The description of the impact evaluation task makes clear that the overall focus is on the innovations achieved or enabled by project outcomes, e.g. "*the innovation dimension of the project"* or *"the impact of ARIADNE in terms of overall innovation".* Therefore the ARIADNE evaluation centres on innovation in the domain of archaeological research, for example, the community building for sharing datasets through e-infrastructure, the data infrastructure and services developed by the project, and others.

Frameworks proposed for the evaluation of research infrastructures suggest various impact dimensions, including scientific, technological, economic, social and environmental impacts (i.e. Expert Group on Research Infrastructures 2010: 43-48; Expert Group on ESFRI Indicators 2013a/b; RIFI[25] FenRIAM guide 2011; Technopolis 2015). Some of these impact dimensions can hardly be applied to e-infrastructures, in particular economic, social and environmental impacts. They concern contributions to economic prosperity and growth, job generation, quality of life, social cohesion and environmental sustainability. These dimensions relate to potential regional impacts which mainly

[25] RIFI - Research Infrastructures: Foresight and Impact (EU, FP7, 3/2009-5/2011) - FenRIAM – Foresight Enriched Research Infrastructure Assessment Methodology, http://www.fenriam.eu

concern the building and operation of major single-sited research infrastructures (e.g. large natural or life sciences facilities).

Concerning the potential of e-infrastructures for the mentioned economic impacts and job generation the IMPACT study notes, *"Indicators for the impact of e-Infrastructures on economy are difficult to assess as there is no direct reporting of realised competitive advantages or economic growth due to infrastructure access. Also, even if e-Infrastructure projects generate new jobs in their affiliated institutions such numbers are of negligible size. If there are impacts they will only evolve and emerge in the long run"* (Fraunhofer ISI & ZEW 2012: 70). Consequently the IMPACT project did not include economic, social and environmental impacts in their set of indicators for an e-infrastructures impact monitoring system (cf. ibid., 147-152 and 161-163).

Scientific and technological impact criteria can be applied to e-infrastructures, including data infrastructures and services. The criteria concern impacts internal as well as external to the research system because improved access to networking, data and computing resources can benefit scientific/ academic institutions and researchers, users from the industrial and public sectors as well as the public in general. However with regard to the impacts the essential differences between the types of existing e-infrastructures must be considered; for example, if the focus is on providing access to data of a research domain (like ARIADNE for archaeology) or on providing computing resources for any type of research, e.g. High-performance or/and Grid-based distributed computing (see *Section 3.3*).

Impact phases and time horizons

The evaluation of research infrastructures must consider the different phases of the RI development and timeframes in which impacts can be realistically expected. In general, the RI development comprises of the design and implementation phase, and the operational phase in which the RI services are provided, maintained and improved.

Care should be taken not to overlook essential results *during* the RI implementation phase (i.e. stakeholder mobilization and participation) or expect in this phase impacts which can only be achieved during the operational phase of a RI. The latter is often the case because funders expect projects achieving impacts in an unrealistic short timeframe. However, as the director of the ERINA+ project put it, *"we have to consider the fact that much of the impact which projects seek to achieve can never be achieved within the short timeframe of a project. Impact may happen two, or three, or more years after the end of a project"* (Andrea Manieri, quoted in Purcell 2013)[26]. When a RI has started regular service provision, still monitoring of relevant indicators over a longer timeframe is required in order to allow a solid assessment of impacts generated.

ARIADNE has completed successfully the implementation of an e-infrastructure and services for archaeological data, while the regular service provision is beyond the funded project lifecycle (i.e. not part of the current grant agreement). Therefore impact indicators for the operational phase of e-infrastructures cannot be applied. However, available results such as usage figures of the ARIADNE portal, publicly launched end of March 2016, are of course reported.

[26] ERINA+, Socio-Economic Impact Assessment for e-Infrastructures Research Projects (EU, FP7, CSA, 7/2010-12/2012), http://www.erinaplus.eu; cf. Manieri 2012 and 2013.

3.5 Impact indicators

For the evaluation of the impacts of ARIADNE a set of indicators of success has been defined for the different project activities according to the I3 model of Integrating Activities. The set is included in the Description of Work of the project (Part B, section 3, pp. 55-56). This set of indicators we call the "ARIADNE impact indicators"[27]. Furthermore the impact evaluation takes account of a number of expected broader impacts of Integrating Activities as stated in the Work Programme 2012 for Research Infrastructures[28]; these expectations we call the "Programme impact indicators".

The ARIADNE and the Programme impact indicators are of a very different character. The indicators defined in the Description of Work are *specific* to the project activities which cover Networking and community building, Trans-national access to RIs and service activities, and Joint research & development activities (I3 model of three groups of project activities). Most of these activities relate directly or indirectly to the data infrastructure and services ARIADNE has implemented.

The broader impacts expected by the Work Programme from Integrating Activities are formulated *generically*, i.e. do not consider essential differences between research infrastructures (e.g. large-scale single-sited RIs versus e-infrastructures). Furthermore they relate to broader schemes (e.g. the European Research Area) and contain assumptions which may or may not hold for a certain type of research infrastructure (i.e. that the RI can enable industrial innovation).

This does not mean that the two different sets of indicators cannot be combined and applied for a systematic account of ARIADNE's impacts. Indeed most of the ARIADNE impact indicators can be mapped onto the broader impacts expected by the RI programme. The sections that follow describe the two sets of indicators and show how they are related.

[27] The set of indicators is included in *Annex A*.

[28] FP7 Work Programme 2012: Capacities: Part 1: Research Infrastructures. European Commission C(2011)5023, 19 July 2011, p.9, https://ec.europa.eu/research/infrastructures/pdf/wp2012_research_infrastructures.pdf

3.5.1 ARIADNE impact indicators

The table below gives an overview of the ARIADNE impact areas, goals and indicators. The indicators and evaluation results are described in detail in *Chapter 4*.

Impact areas and goals	***Indicators***
Community building for innovation *(Networking)* Overall goal: Involve stakeholders (institutions and end-users) and foster co-operation between research infrastructures (e-infrastructure) and scientific communities	○ Involvement of archaeological and cultural heritage institutions from Europe and beyond ○ Participation of community members (end-users) in project activities ○ Innovation agenda and action plan, including sustainability plan
Dissemination *(Networking)* Overall goal: Promote awareness of RIs and good practices (e.g. data management and sharing)	○ Events on data sharing, e-RIs and digital archives (e.g. conference sessions, workshops, …) ○ Dissemination of related information and guides to good practice
Training and usage of data services *(Transnational access and services)* Overall goal: Support scientific communities in their access to research infrastructure resources and services such as training and online access to content/data	○ Study visits to RIs for project-related skills development (Trans-national access – TNA) ○ Other training provided (tutorials and short training courses at conferences and other events) ○ Online access to digital resources and services of individual RIs
Integrated access to RI data resources *(Joint research & development)* Overall goal: Bring together and integrate, on a European scale, digital archives ensuring that researchers have a wider and more efficient access to data they require to conduct their research	○ Critical mass of content/data: Increase in volume and richness of accessible data (e.g. reports, images, 3D etc.) ○ Overcome fragmentation: Percentage of datasets integrated with appropriate technologies (e.g. geo-spatial, linked data and other methods) ○ Unified access: Percentage of datasets accessible through a common interface and innovative services (according to dataset types) ○ Data maintenance and curation: Long-term access to data records
Innovation in digital archaeological practices *(Joint research & development)* Overall goal: Enable advanced or new digital methods and demonstrate the innovative capabilities	○ Progress in data documentation, linking, processing and visualisation (e.g. extended CRM/ontology, linked data, data mining/NLP) ○ Demonstrated capability to support advanced or new digital methods (pilots/demonstrators)

3.5.2 Programme impact indicators

The impacts expected by the FP7 Work Programme for Research Infrastructures (2012) from Integrating Activities are formulated generically for all types of research infrastructures. The expectations are not elaborated in a systematic set of impact dimensions and indicators but formulated in a text of the Work Programme (the text is reproduced in *Annex A*). In order to address the expectations the stated impacts had to be extracted, organised, and elaborated further for using them in the ARIADNE impact evaluation. Below we present the elaborated "Programme impact indicators"; background for each indicator and the results of the impact evaluation are given in *Chapter 5*.

Impact areas and goals	***Indicators***
Structuring impact on the European Research Area Overall goal: Promote cooperation and connect research communities and resources (data, ICT services) at the European level	○ European-level e-infrastructure for the field of archaeology, enabling cross-country data sharing, integration and access ○ Involvement of a large community of stakeholders in the e-infrastructure and other project activities ○ High-level recognition and support of the initiative
Coordinated evolution of Research Infrastructures, incl. e-infrastructures Overall goal: Contribute to the coordinated development/evolution, synergies and integration of e-infrastructures in the target area	○ Knowledge exchange and coordination with other e-infrastructure initiatives in the field of humanities and heritage sciences ○ Collaboration with other initiatives to enable data integration and e-infrastructure based research in the multi-disciplinary field of archaeology
Improved development, access/use and sustainable operation of RIs Overall goal: Support optimal development, operation and use of integrated data archives, ensuring that researchers and other users have reliable and efficient access to data they require for research and other purposes	○ Integrated access to archaeological data archives enabling use of data from different European countries ○ Identification of the requirements for and sharing of best practices in the sustainable operation of data archives ○ Promotion of new data centres and knowledge transfer from established centres
Cross-disciplinary fertilisation Overall goal: Enable fertilisation between different fields of research, e.g. sharing of data, conceptual understanding and integration, collaboration on new tools/services	○ Data services relevant to all domains of the multi-disciplinary field of archaeological research ○ Fostering cross-disciplinary fertilisation among researchers of different domains (e.g. data sharing and integration, collaboration of scholars and technologists for new tools/services)
Sharing of knowledge and technologies and potential industrial innovation Overall goal: Share new knowledge and technical solutions (tools/services) across fields of research, with related public sector bodies and businesses, and enable innovation beyond the research sector	○ Sharing of new knowledge (models, methods) and advanced or new tools and services across fields of research ○ Project outcomes also available for public sector organisations and businesses ○ Potential for innovation of businesses active in archaeology and cultural heritage

3.5.3 Mapped impact indicators/results

This table shows the mapping of the ARIADNE and Programme impact indicators/targets and how both the project-specific and broader programme targets have been achieved.

ARIADNE impact indicators	***Results mapped to the Programme impact indicators***	***Programme impact indicators***
Community building for innovation ○ Involvement of archaeological and cultural heritage institutions from Europe and beyond ○ Participation of community members (end-users) in project activities ○ Innovation agenda & action plan, and Sustainability plan **Dissemination of project information and good practice** ○ Event organisation and participation: (co-) organised events on data management & sharing, digital archives and e-infrastructures ○ Promoting awareness through project website, social media, information material ○ Dissemination of guides to good practice, research papers and other project products	○ ***Institutions reached and involved:*** 65 European archaeology and cultural heritage institutions of 24 EU member states and two other countries (Iceland, Norway); 19 non-European institutions and international initiatives ○ ***End-users reached and involved****:* 10,500 researchers and practitioners (conservative estimate) involved in project activities (user needs surveys, TNA study visits and other training, over 200 (co-)organised events and presentations at others; 30 times larger participation than the membership of the core archaeological ICT organisation CAA (350), 5 times larger than the membership of the European Association of Archaeologists (2000+), and about 32% of the number of archaeologists working in Europe (33,000) ○ ***High-level recognition of ARIADNE****:* European Archaeological Council (strongly encourages data sharing through ARIADNE) and European Strategy Forum on Research Infrastructures (acknowledges ARIADNE as the core integrator of archaeological research resources); positive effects of ARIADNE also recognised by national institutions as well as individual researchers	**Structuring impact on the European Research Area** ○ Involvement of a large community of stakeholders in the e-infrastructure and other project activities ○ High-level recognition and support of the initiative
Integrated access to RI data resources, e-infrastructure and services ○ Allowing integrated data search and access: interoperable data records of different European providers ○ Overcoming data fragmentation: data records searchable based on subjects, location/map-based and cultural chronology (date ranges) ○ Offering unified search & access: data portal	○ ***European-level data infrastructure and services****:* providing direction for and preventing fragmentation of efforts for data mobilisation, sharing and integration ○ ***Data portal services / usage****:* integrate and allow cross-archive discovery of and access to various archaeological data resources; 10,800 visitors, 15,400 sessions, 69,000 page views in the first year of operation	**Structuring impact on the European Research Area** ○ European-level e-infrastructure for the field of archaeology, enabling cross-country data sharing, integration and access

Community building for innovation – continued: e-infrastructures	○ ***Dedicated events for e-infrastructure knowledge exchange and coordination***: 16 conferences, workshops and meeting involving DARIAH, CENDARI, CLARIN, E-RIHS, European Open Science Cloud, Europeana, IPERION-CH, JPI on Cultural Heritage and Global Change, PARTHENOS, TGIR Huma-Num (France) and others; participation of 800 people (conservative estimate) ○ ***Cooperation with other initiatives***: 10 European archaeology and cultural heritage projects, including RIs/e-infrastructures such as CENDARI, DARIAH, E-RIHS, Europeana, PARTHENOS, and domain institutions/projects in prehistory, ancient history, environmental archaeology, chronologies (dendrochronology, cultural periods) and others ○ ***Development of common data registration and access services***, i.e. harmonization of data catalogues following and extending the model developed by ARIADNE	**Coordinated evolution of Research Infrastructures – e-infrastructures** ○ Knowledge exchange and coordination with other e-infrastructure initiatives in the field of humanities and heritage sciences ○ Collaboration with other initiatives to enable data integration and e-infrastructure based research in the multi-disciplinary field of archaeology
Community building for innovation – continued: digital archives	○ ***Implemented cross-archive data discovery and access*** *(see above)* ○ ***Sharing of knowledge in sustainable digital archiving***: 13 dedicated events, 11 organised by ARIADNE, involved the leading organisation in the field and put the sharing of data through digital archives on the agenda of the research community; over 500 participants (conservative estimate) ○ ***Promotion of new archaeological data archives***: i.e. in Austria, Hungary, Ireland and Slovenia; knowledge transfer for state-of-the-art archives between established and new initiatives	**Improved development, access/use and sustainable operation of RIs – digital archives** ○ Integrated access to archaeological data archives enabling use of data from different European countries ○ Identification of the requirements for and sharing of best practices in the sustainable operation of data archives ○ Promotion of new data centres and knowledge transfer from established centres
Training and usage of data services ○ Online access to digital resources and services of RIs – e-infrastructure services and digital archives ○ Study visits to RIs for project-related skills development (Trans-national access – TNA) ○ Other training provided (tutorials and short courses at conferences and other events)	○ ***Data portal services / usage***: see above ○ ***Use of other advanced services***: ARIADNE Visual Media & Landscape Services in use by many research and dissemination projects ○ ***TNA study visits and other training***: focused on skills and tools for dataset creation & management, use of CIDOC-CRM and other vocabularies, 2D/3D documentation; over 500 participants ○ ***Cross-domain fertilisation***: based on improved data sharing, conceptual understanding of different fields of research (i.e. use	**Cross-disciplinary fertilisation** ○ Data services relevant to all domains of the multi-disciplinary field of archaeological research ○ Fostering cross-disciplinary fertilisation among researchers of different domains (e.g. data sharing and integration, collaboration of scholars and technologists for new tools/services)

	of extended CIDOC-CRM and other vocabularies), collaboration of scholars and technologists on new tools/services	
Innovation in digital archaeological practices ○ Progress in data documentation, linking, processing and visualisation (e.g. extended CRM/ontology, linked data, data mining/NLP) ○ Demonstrated capability to support advanced or new digital methods (pilots/demonstrators)	○ ***Substantial progress achieved with regard to data documentation, linking, processing and visualisation:*** i.e. extended CIDOC-CRM (i.e. CRMarcheo, CRMba, CRMsci and other extensions); application of linked data methods (i.e. vocabulary mapping), NLP of archaeological reports (metadata generation), ARIADNE visual media and landscape services ○ ***Demonstrated capability to support advanced or new digital methods****:* several demonstrators implemented ranging from experimental to productive solutions ○ ***Project results communicated (sector events, trainings, publications) and publicly available****:* advanced models, methods, tools/services available for research institutions/projects, public sector organisations and private businesses ○ ***Potential innovation in archaeology and cultural heritage businesses/industry****:* through enhanced access to shared knowledge (i.e. fieldwork reports of contract archaeologists and academic research), and information about archaeological sites and monuments, i.e. for heritage-led regional development and cultural heritage communication ○ ***Potential innovation by ICT businesses****:* low potential for ICT businesses to provide e-infrastructure and services (e.g. data archives/services) for archaeological research	**Sharing of knowledge and technologies and potential industrial innovation** ○ Sharing of new knowledge (models, methods) and advanced or new tools and services across fields of research ○ Project outcomes also available for public sector organisations and businesses ○ Potential for innovation of businesses active in archaeology and cultural heritage

4 ARIADNE impact indicators and results

ARIADNE is an Integrating Activity set up according to the Integrated Infrastructures Initiatives - I3 model, which means that the project combines Networking, Trans-national access and/or service provision, and Joint research activities. A set of indicators of success has been defined for the different I3 activities and included in the project's Description of Work (Part B, section 3, pp. 55-56)[29].

This chapter presents the results of the impact evaluation for these "ARIADNE impact indicators", while *Chapter 5* addresses the expected broader impacts of Integrating Activity projects as stated in the Work Programme 2012 for Research Infrastructures.

Some of the indicators in the Description of Work (ARIADNE impact indicators) have not been specific enough to allow for measuring the achieved results. In such cases more specific and/or additional targets have been defined. The target for each indicator is given in the sections below which provide a detailed record of the results achieved.

4.1 Community building for innovation

4.1.1 Brief description

Community building for innovation in data-related archaeological practices in Europe and beyond has been one of the core goals of the project. Institutions and individuals have been involved in various project activities, for example, identification of needs and requirements in e-infrastructure and data services, fostering co-operation between European and international initiatives, sharing of digital archaeological data, among others.

In the project's Description of Work the following impact indicators have been defined with regard to the community building activities:

- Involvement and active participation by the major institutional stakeholders from all EU Members States, comprising the leading: Antiquity authorities and other public authorities, Archaeological research centres, and Research and professional associations.
- Liaisons with relevant research institutions and initiatives outside Europe.
- At least 400 end-users from the above and other institutions participating in project activities (e.g. special interest groups, conference sessions, etc.).
- Innovation Agenda and Action Plan endorsed, published and put into practice by the members of the consortium and affiliated institutions.
- Business Model evaluated by external experts and supported by the members of the consortium and affiliated institutions.

The sections below provide a detailed record of the achievements.

[29] The tabular overview of this set of indicators is included in *Annex A*.

4.1.2 Involvement of institutions and projects in Europe

Impact indicator defined in the DoW: Involvement and active participation by the major institutional stakeholders from all EU Members States, comprising the leading: Antiquity authorities and other public authorities, Archaeological research centres, and Research and professional associations.

More specific and/or additional indicators:	***Results***
○ ARIADNE partners, cooperation agreements and other liaisons with European institutions active in the field of archaeology/heritage in Europe (e.g. collaboration on sharing datasets, thesauri, methods/tools, etc.)	65 European institutions from 24 EU Member States and 2 from other European countries, 15 formal cooperation agreements
○ Cooperation with European projects on an informal or formal basis (e.g. Memorandum of Understanding)	10 European projects, with a focus on e-infrastructure, digital research tools/services, specific datasets and standards

Involvement of archaeological/heritage institutions in Europe

The following table gives an overview of the European antiquity/heritage authorities and other public authorities, archaeological and other heritage research centres, and research and professional associations that have been involved in the ARIADNE initiative. Technological research & development organisations are not included.

The table lists formal ARIADNE partners, institutions involved based on a cooperation agreement or informal cooperation, institutions that sent researchers to participate in ARIADNE Transnational Access (TNA) trainings for institutional projects (i.e. in view also to provide data to ARIADNE), and institutions with which opportunities to collaborate have been discussed one or more times. Included are also institutions that participate in the NAHAN initiative (see information below). The involvement mostly concerns the building and sharing of databases, use of common vocabularies (e.g. thesauri), and expertise in special subject matters, i.e. conservation of archaeological heritage, digital archiving, documentation of scientific datasets, application of the CIDOC-CRM ontology.

Present are 65 institutions, including 17 ARIADNE partners in the relevant categories. Formal cooperation agreements have been signed with 15 other institutions. At least one, often more institutions are present of 24 of the 28 EU Member States and two other European countries (Iceland, Norway). Yet to be involved in the ARIADNE initiative are archaeological institutions in Croatia, Latvia, Luxembourg and Slovakia.

Country	***Institution***	***Type of coop.***
Austria	Austrian Academy of Sciences (ÖAW), Institute for Oriental and European Archaeology (OREA)	ARIADNE partner
	Austrian Archaeological Institute, since 1.1.2016 belongs to the ÖAW	Part of ÖAW
Belgium	Wallonie, Département du Patrimoine - Direction de l'Archéologie	Cooperation agreement in preparation
	Vrije Universiteit Brussel, dept. Art and Archaeology: online database for the recording of metal-detector finds in Flanders (MEDEA project, 2014-2017); the project director participated in TNA (potential ARIADNE data provider)	Intends registering the MEDEA finds data in ARIADNE

	PACKED - Centre of Expertise in Digital Heritage, Brussels: Supports digital heritage projects in Belgium; one digital archivist participated in TNA (see above)	MEDEA project
Bulgaria	National Institute of Archaeology with Museum - Bulgarian Academy of Sciences (NIAM-BAS)	ARIADNE partner
Cyprus	The Cyprus Institute - Science and Technology in Archaeology Research Center	ARIADNE partner
Czech Republic	Archeologicky ustav AV CR / Institute of Archaeology of the Academy of Science (ARUP-CAS)	ARIADNE partner
Denmark	Aarhus University, School of Culture and Society: Danske Detektorfund (DIME) project for a national database of metal-detector finds; two archaeologists with IT experience participated in TNA (potential ARIADNE data provider)	Cooperation agreement
	Moesgaard Museum, Aarhus: Museum dedicated to archaeology and ethnography; participates in the DIME project; one archaeologist participated in TNA (see above)	Danske Detektorfund (DIME) project
Estonia	Conservation and Digitization Centre Kanut, Tallinn: Since 2006 the conservation centre has digitised tens of thousands legacy photographs, negatives, documents, prints, etc. The documentation and digitisation department manager participated in TNA (potential ARIADNE data provider)	Documentation of heritage conservation measures
Finland	University of Helsinki, dept. Philosophy, History, Culture and Art Studies; contact: principal investigator Suzie Thomas, liaison ADS / J. Richards (potential ARIADNE data provider)	Planned database of metal-detector finds
	University of Oulu, Memornet Doctoral Programme – Archaeology, Prof. Jari Okkonon (Anthropology Department), Teija Oikarinen (doctoral student), liaison: ADS, H. Wright	Contributed to an excavation data management survey (ARIADNE 2015e)
France	Institut National des Recherches Archéologiques Préventives (INRAP)	ARIADNE partner
	Fédération et ressources sur l'Antiquité (FRANTIQ), Centre National de la Recherche Scientifique (PACTOLS multi-lingual thesaurus for antiquity and archaeology from prehistory to the industrial age)	Cooperation agreement
	Archéologie de la France Informations: AdlFI publishes information about archaeological research work conducted in France; contact: Cécile Tuarze, Équipe OpenEdition.org, liaison AIAC, L. Fentress	Work on directly linking information with Fasti Online and ARIADNE
	Maison de l'Orient et de la Méditerranée – MOM (Université Lyon 2, CNRS): Artefacts - Online Encyclopedia of Archaeological Small Finds, director Michel Feugère, liaison AIAC, L. Fentress; one MOM researcher participated in TNA (potential ARIADNE data provider)	Work towards incorporating the Artefacts database in ARIADNE

	Université de Cergy-Pontaise, Laboratoire ETIS: PARCOURS project on documentation of heritage conservation; two researchers participated in TNA (potential ARIADNE data provider)	Heritage documentation
	Université de Tours, Laboratoire Archéologie et Territoires, CNRS: Archives du Sol (Soil Archives) Database; one archaeological IT expert participated in TNA (potential ARIADNE data provider)	Soil Database (based on CIDOC-CRM)
	ArkéoTopia: supports archaeological researchers and students in making their work accessible and relevant to the wider public, i.e. open data; director Jean-Olivier Gransard-Desmond, liaison SRFG, G. Geser	Exchange of expertise in open data sharing
	Archives nationales d'outre-mer at the Centre Camille Jullian of the Université d'Aix-Marseille and CNRS, focuses on Mediterranean and African Archaeology; contact: prof. Marie-Brigitte Carre, liaison AIAC, L. Fentress	Reports of archaeo-logical investigations in North Africa (NAHAN project)
	French school in Madrid / Casa di Velasquez: section ancient and mediaeval studies; director Laurent Callegarin, liaison AIAC, L. Fentress	Reports of archaeol. investigations in North Africa (NAHAN)
	École française de Rome: section archaeology with a focus on Algeria, Marocco and Tunisia (end of the 19th century to the World War II), and of course Italy; director Catherine Virlouvet, liaison AIAC, L. Fentress	Reports of archaeol. investigations in North Africa (NAHAN)
Germany	Deutsches Archäologisches Institut (DAI)	ARIADNE partner
	IANUS - Research Data Centre for Archaeology and Classical Studies in Germany	Exchange of expertise in data archiving and access
Greece	The British School at Athens: AGOnline - Archaeology in Greece Online database of excavation projects; director John Bennet, liaison AIAC, L. Fentress	Intends to contribute AGOnline through integration with Fasti Online
Hungary	Hungarian National Museum, National Heritage Protection Centre (MNM-NOK)	ARIADNE partner
Iceland	Fornleifastofnun Íslands / The Institute of Archaeology, Reykjavík, Iceland: Icelandic Archaeo-Historical Database; one archaeologist with experience in IT participated in TNA (potential ARIADNE data provider)	Cooperation agreement
Ireland	The Discovery Programme LBG	ARIADNE partner
	Heritage Council: coordination of national initiatives for digital heritage in Ireland, liaison Discovery Programme, A. Corns	Initiative for a digital archive of heritage and archaeology
	Transport Infrastructure Ireland (TII): One project manager participated in TNA in view of providing archaeological survey data to ARIADNE (via Discovery Programme)	Provision of archaeo-logical survey data
Italy	Italian Ministry of Cultural Assets and Activities - Central	ARIADNE partner

	Institute for the Union Catalogue (ICCU) and Central Institute for Cataloguing and Documentation (ICCD)	
	Associazione Internazionale di Archeologia Classica (AIAC)	ARIADNE partner
	Soprintendenza Speciale per il Colosseo (SSCol), Il Museo Nazionale Romano e l'Area Archeologica di Roma, Italy	Cooperation agreement
	Institute of Cultural Heritage, Regione Emilia Romagna, Italy	Cooperation agreement
	University of Verona, SITAVR - Sistema informativo territoriale archeologico di Verona (provided by Dipartimento TeSIS e di Informatica di Verona), Italy	Cooperation agreement
	Archivio dello Stato Italiano, director Eugenio lo Sardo, liaison: AIAC, L. Fentress	Reports of archaeol. investigations in North Africa (NAHAN)
	MAPPA: open data repository at the University of Pisa, repository director Gabriele Gattiglia, liaison: ADS, J. Richards	Exchange of expertise in data archiving and access
	Università di Siena, Dipartimento di Archeologia e Storia delle Arti, prof. Emanuele Papi, liaison AIAC, L. Fentress	Reports of archaeol. investigations in North Africa (NAHAN)
Lithuania	University of Vilnius, Faculties of Communication and History (incl. the Department of Archaeology); two researchers participated in TNA (potential ARIADNE data provider)	Cooperation agreement
Malta	Heritage Malta, the national agency for museums, conservation practice and cultural heritage; deputy superintendent Nathaniel Cutajar, liaison: AIAC, L. Fentress)	Data management, data sharing mechanisms
	University of Malta, Department of Archaeology: Legacy database of excavations going back a hundred years; prof. Anthony Bonanno, liaison AIAC, L. Fentress	Data enhancement, (legacy databases)
Netherlands	KNAW-DANS - Data Archiving and Networked Services	ARIADNE partner
	Leiden University, Faculty of Archaeology	ARIADNE partner
	Vrije Universiteit Amsterdam, Centre for Research and Education in Geo-Information Science, Spatial Information Laboratory (SPINlab): Via Appia project; two VU Amsterdam researchers (archaeologist, IT expert) participated in TNA (potential ARIADNE data provider)	Cooperation agreement
Norway	University of Oslo, Museum of Cultural History: Digital Field Museum and MUSIT; one museum IT expert participated in TNA (potential ARIADNE data provider)	Cooperation agreement
Poland	National Heritage Board of Poland, Department for Documentation & Monuments Databases, head of dept. Arkadiusz Kołodziej; Department of Archaeology, Agnieszka Oniszczuk, senior specialist in archaeology; liaison ADS, H. Wright	Interest in domain archive solution, contributed report to an archiving survey (ARIADNE 2016h)

Portugal	Directorate-General for Cultural Heritage, Lisbon, Portugal	Cooperation agreement
	University of Minho, Archaeology Unit, Braga, Portugal: Bracara Augusta – Domus of Carvalheiras project; one archaeological IT expert participated in TNA (potential ARIADNE data provider)	Cooperation agreement
Romania	Arheovest Timisoara Association	ARIADNE partner
Slovenia	Institute of Archaeology of the Scientific Research Centre of the Slovenian Academy of Sciences and Arts (ZRC-SAZU)	ARIADNE partner
Spain	Spanish National Research Council, Institute of Heritage Sciences (CSIC-Incipit)	ARIADNE partner
	Andalusian Institute of Historical Heritage (IAPH), Sevilla, Spain; two IAPH staff (archaeologist, archivist) participated in TNA to enhance the Andalusian Information System of Cultural Heritage (potential ARIADNE data provider)	Cooperation agreement
	National Research Centre on Human Evolution (CENIEH), Burgos, Spain; two CENIEH staff (project director, IT expert) participated in TNA (potential ARIADNE data provider)	Cooperation agreement
	University Research Institute for Iberian Archaeology, University of Jaén, Spain; one archaeologist participated in TNA (potential ARIADNE data provider)	Cooperation agreement
	University of Salamanca, Department of Prehistory, Ancient History and Archaeology: Fasti Online Spain project, open access Zephyrus - Revista de prehistoria y arqueología, prof. María de las Cruces Blázquez, liaison: AIAC, L. Fentress)	Increase coverage of excavation projects in Fasti and ARIADNE
Sweden	Swedish National Data Service - University of Gothenburg	ARIADNE partner
	University of Umea, SEAD - The Strategic Environmental Archaeology Database, Sweden; cooperation agreement on sharing expertise in the integration of environmental data	Cooperation agreement
	Uppsala University, Department of Archaeology and Ancient History: GIS data from excavations in several counties; two researchers (archaeologist, PhD student) participated in TNA (potential ARIADNE data provider)	GIS datasets
United Kingdom	Archaeology Data Service, University of York	ARIADNE partner
	Historic Environment Scotland: National Record of the Historic Environment; one spatial information manager participated in TNA (potential ARIADNE data provider)	Geo-spatial datasets
	University of Oxford, Research Laboratory for Archaeology and the History of Art (RLAHA): FLAME - Flow of Ancient Metal Across Eurasia, ERC-funded project, four researchers (archaeologists, IT expert) participated in TNA (potential ARIADNE data provider)	FLAME: Definition of a CRM based model for scientific studies (ancient metallurgy)

	University of Oxford, Beazley Archive: the archive leads the CLAROS project, an online collaboration of ancient and classical arts collections and research centres in the UK, Germany and Greece; opportunities for collaboration have been discussed with the CLAROS project director	CLAROS: Ancient and classical arts collections
	University of Southampton, Department of Archaeology: has datasets from a range of projects (i.e. Portus Project, Roman Port Networks and others); prof. Simon Keay (also director of archaeology at the British School at Rome), liaison AIAC, L. Fentress	Integration of datasets for research (i.e. trade networks)
	SEAHA - Centre for Doctoral Training in Science and Engineering in Arts Heritage and Archaeology, provision of training course by CNR-ISTI	Training of PhD students in the use of novel digital tools
	Society for Libyan Studies, London, is a British academic body and charitable organisation; currently digitises 3000 archival items; online photographic reference collection of the Libyan Antiquities at Risk (LAaR) project; prof. Corisande Fenwick, liaison: AIAC, L. Fentress	Reports of archaeo-logical. investigations in North Africa (NAHAN project)

The overview of liaisons and cooperative activities with European institutions includes two examples that can illustrate the range of initiatives ARIADNE supports for making data accessible through the ARIADNE portal. The examples are European databases of metal-detector finds and the North African Heritage Archive Network (NAHAN) initiative. These represent very different actors, data resources, and time-horizons.

European databases of metal-detector finds

A number of European institutions had the idea of establishing a European portal to join up existing and planned databases of metal-detector finds, which are important research resources for archaeo-logists. In a meeting of representatives of the database projects in Aarhus, Denmark on the 23rd of June 2016 Julian Richards (ADS) presented the ARIADNE portal. The group then decided to work with ARIADNE with the aim to employ the ARIADNE data catalogue/portal for integrated access to their data. The institutions and projects are

- British Museum, Portable Antiquities Scheme (PAS) database (UK): the established and very successful PAS provides the role model for other initiatives in this field; PAS collects finds data in England and Wales, while data of finds in Scotland are collected via OASIS[30] and uploaded to ADS and Historic Environment Scotland's Canmore database[31];
- University Aarhus, School of Culture and Society (Denmark): the project Danske Detektorfund will set up a national database; ARIADNE has a cooperation agreement with the School of Culture and Society;
- Vrije Universiteit Brussel, dept. Art and Archaeology (Belgium): develops an online platform and database for the voluntary recording of metal-detector finds in Flanders (MEDEA project, 2014-2017);

[30] OASIS - Online Access to the Index of Archaeological Investigations, http://oasis.ac.uk

[31] Historic Environment Scotland: Canmore database, https://www.historicenvironment.scot/archives-and-research/archives-and-collections/canmore-database/

- Vrije Universiteit Amsterdam, Faculty for Humanities (Netherlands): leads a funded research project for a metal-detector finds database for the Netherlands; the project plans archiving data with DANS and to contribute to ARIADNE via that route;
- University of Helsinki, dept. Philosophy, History, Culture and Art Studies (Finland): intends developing a database of metal-detector finds in Finland (currently applying for funding).

The initiative concerns archaeological/historical finds by hobby metal-detectorists who have shown great willingness to provide records and images of the finds in the Portable Antiquities Scheme (UK). The new databases and contribution schemes are being prepared by university institutes. These data resources are in ARIADNE's short-term horizon of additional data acquisition.

Registration of the databases would use the finds database resource type of the ARIADNE ACDM and records would be integrated at item level, which means each data record (description, images) individually. Furthermore CIDOC-CRM and relevant extensions would be employed to allow advanced search across these and other data on the ARIADNE portal. Researchers and archivists with IT experience of the new finds databases participated in ARIADNE TNA trainings on the ARIADNE standards and facilities in view of future provision of data.

North African Heritage Archive Network (NAHAN)

The NAHAN initiative has been promoted by ARIADNE partners and involves several archaeological archives in Europe, North African countries (Algeria, Libya, Morocco, Tunisia)[32], and project archives of archaeologists of other countries (e.g. Canada and USA). Under the aegis of the International Center for the Study of the Preservation and Restoration of Cultural Property - ICCROM (Rome), the project goal is to assemble on one platform the archaeological catalogues of these archives. The first NAHAN meeting was held on the 22nd of February 2016 at the École française de Rome. The NAHAN Memorandum of Understanding covers the development of the joint open access catalogue, digitisation of collections, intellectual copyrights, training for digital content curators (where this is needed), outreach and dissemination. The NAHAN cataloguing platform has been presented by the German Archaeological Institute at the latest network meeting on the 16th of January 2017 at the École française de Rome. It is based on the metadata schema of DAI's Arachne database which has been mapped to the ARIADNE dataset catalogue model. Based on this approach the NAHAN records can be easily included in the ARIADNE registry and portal.

This is an initiative of archives and the records concern content of archaeological documentation (i.e. reports, site maps, photographs, drawings, etc.) of surveys and excavations conducted in North African countries for decades. The intention is to inspire and support new research based on the aggregated records and direct researchers to the content of often unpublished past archaeological work. These data resources are in ARIADNE's medium to long-term horizon of additional data acquisition. Concerning the archives in Europe as well as in Canada and the United States we see a medium-term horizon, while the archives in the North African countries may need several years to prepare and make available a large number of records.

Cooperation with European archaeology and cultural heritage projects

During the project period ARIADNE collaborated with 10 European projects on a wide range of topics. These include common policies and interoperability of e-infrastructures, heritage sciences (with focus on tangible heritage), specific datasets/content archives and standards, tools/services needed by researchers in the digital humanities, skills development in remote surveying techniques and data, and public archaeology.

[32] The organisations in the North African countries that participate in NAHAN are included in the overview in the section "Involvement of institutions outside Europe" below.

Project	***Brief description***	***Type of coop.***
ArcLand	ArchaeoLandscapes Europe (Culture Programme, 9/2010-8/2015, 68 organisations including from Australia and the United States); ArcLand focused on removing imbalances in skills/use of surveying techniques such as aerial photography, satellite imagery, LiDAR and others	Skills development in an area not covered by the ARIADNE training programme; MoU
CENDARI	CENDARI - Collaborative European Digital Archive Infrastructure (FP7, 2/2012-1/2016, 14 partners): CENDARI mobilised and integrated digital archives for the medieval and World War I eras	Medieval content archives
DARIAH	DARIAH - Digital Research Infrastructure for the Arts and Humanities (legal entity: ERIC), 17 EU Member States participate in DARIAH (together about 120 institutions)	E-infrastructure, network of VCCs; MoU
DCH-RP	Digital Cultural Heritage Roadmap for Preservation - Open Science Infrastructure for Digital Cultural Heritage in 2020 (FP7, 10/2012-9/2014); DCH-RP mobilised stakeholders to establish a common roadmap for the preservation of digital heritage	Scientific collaboration and dissemination of knowledge in digital archaeology; MoU
EAGLE	Europeana Network of Ancient Greek and Latin Epigraphy (ICT-PSP, 4/2013-3/2016, 19 partners); EAGLE developed epigraphic vocabularies and assembled collections into a searchable database	Epigraphic standards and datasets; MoU
eCloud	Europeana Cloud (ICT-PSP, 2/2013-1/2016, 34 partners); eCloud explored requirements of researchers for using Europeana and developed relevant tools and services	Content and tools/ services required by digital humanities researchers; MoU
E-RIHS	European Research Infrastructure for Heritage Science (ESFRI Roadmap project: preparation phase, 2017-2020); already active national nodes include E-RIHS.it, coordinated by CNR, and E-RIHS.gr, coordinated by FORTH	Heritage Sciences with focus on tangible heritage
Europeana	Europeana: The European gateway to digitised cultural heritage. Regular knowledge exchange at coordination meetings of humanities e-infrastructures; ARIADNE partners support the Europeana Research initiative; but the collaboration may also foster interest of teachers, students and the wider public in archaeology, classical studies and related disciplines	Support of Europeana Research with regard to research tools; in previous projects ARIADNE partners provided content to Europeana
NEARCH	New ways of Engaging audiences, Activating societal relations and Renewing practices in Cultural Heritage (Culture Programme, 2013-2018, 16 partners); NEARCH explores novel approaches of public participation in archaeology	Public archaeology
PARTHENOS	Pooling Activities, Resources and Tools for Heritage E-research Networking, Optimization and Synergies (H2020, 5/2015-4/2019): strong collaboration with ARIADNE as partners are involved in both projects (coordinator of both is PIN Vast-Lab, prof. F. Niccolucci)	Common policies and interoperability of e-infrastructures for the humanities and heritage sciences

4.1.3 Involvement of institutions outside Europe and international initiatives

Impact indicator defined in the DoW: Liaisons with relevant research institutions and initiatives outside Europe.

More specific and/or additional indicators: In addition, liaisons with research data repositories outside Europe and international initiatives with participation of European institutions and projects are included.

The table below gives an overview of the 19 liaisons and activities with institutions outside of Europe and international projects (formal cooperation agreements have been signed with 6 institutions/ projects). The spectrum of institutions and projects ranges from national and international authorities (i.e. Israel Antiquities Authority, ICCROM) to special interest groups (i.e. CAA Linked Data SIG) and specific data and vocabulary resources (i.e. PeriodO). Most liaisons concerned collaboration on shared content/data resources and use of common vocabulary. More specifically, the topics included sharing of reports and datasets from archaeological surveys, excavations and conservation projects, exchange of expertise in data archiving and access, use of common vocabularies, fostering of data linking based on W3C recommended Linked Data standards.

Country	***Institution / international initiative***	***Type of coop.***
International	ICCROM - International Center for the Study of the Preservation and Restoration of Cultural Property, Rome; cooperation with ARIADNE partner Fasti Online to document conservation work on monuments and objects across Europe in "Fasti Conservation"[33]; over 50 professionals in archaeological conservation have been introduced to the initiative, most have joined the advisory board of the project; director Stefano De Caro, liaison AIAC, L. Fentress	Documentation of major archaeological conservation work, also formal host for the NAHAN project
International	Pelagios: a collective of over 40 institutions and projects in Europe and the United States that links content (texts, maps, archaeological records) which relates to ancient places; the linking is based on unique URI's for place names provided by the Pleiades gazetteer; Pelagios project director Leif Isaksen (University of Lancaster, UK), liaison USW, D. Tudhope	Exchange of expertise in data linking[34], Fasti Online (AIAC) and Arachne (DAI) supply data to Pelagios
International	Nomisma: integrates numismatic datasets of the American Numismatic Society (ANS) and institutions in Europe based on Linked Data methods using controlled vocabulary for describing coins; ANS committee member Sebastian Heath, liaison USW, D. Tudhope	Use of the Nomisma vocabulary and datasets in ARIADNE
International	Corpus Signorum Imperii Romani, hosted by Oxford University's Classical Art Research Centre; CSIR is an international project coord. by ARIADNE partner AIAC; CSIR vice-president Peter Stewart, liaison AIAC, L. Fentress	Publications on corpora of Roman sculpture

[33] ARIADNE (2015-09-08): Fasti Online launches Archaeological Conservation database, http://www.ariadne-infrastructure.eu/News/New-Archaeological-Conservation-database

[34] ARIADNE (2015-08-07): ARIADNE at Linked Pasts, http://ariadne-infrastructure.eu/News/ARIADNE-at-Linked-Pasts

International	CAA Linked Data SIG, special interest group related to the Computer Applications and Quantitative Methods in Archaeology (CAA) organisation; SIG coordinator Leif Isaksen (University of Lancaster, UK), liaison USW, D. Tudhope	Promotion of projects on archaeological Linked Data
Australia	FAIMS - Federated Archaeological Information Management Systems Project, led by Macquarie University in collaboration with ten Australian and overseas university partners; prof. Shawn Ross (Macquarie University, Department of Ancient History), liaison ADS, J. Richards	*Cooperation agreement* Offers a suite of web and mobile documentation tools
Israel	Israel Antiquities Authority, Jerusalem; intends to share relevant datasets and vocabulary; liaison PIN, F. Niccolucci	*Cooperation agreement* Sharing of datasets
Mexico	National Institute of Anthropology and History (INAH): The ARIADNE coordinator met with INAH to discuss cooperation topics (Mexico City, 5.12.2014)[35]	Scientific cooperation
USA	MAGIS - Mediterranean Archaeology GIS: database of over 380 surveys in the Mediterranean since 1980, project lead DePauw University, Pedar W. Foss, liaison AIAC, L.Fentress; cooperation to link the MAGIS database to Fasti Online and ARIADNE	*Cooperation agreement* Sharing of the MAGIS database of survey projects
USA	Open Context: archaeological data publication platform offered by the Alexandria Archive Institute; data of projects in Cyprus, England, Germany, Italy, Turkey, Syria, Jordan, Israel, Palestine, Iran, Iraq, Australia, China, India, and the United States (73 projects); published data are deposited with the California Digital Library; program director Eric Kansa, liaison DAI, R. Förtsch	*Cooperation agreement* Also hosting and use of the platform by DAI, contributions to its further development
USA	tDAR - The Digital Archaeological Record, data archive and access service of the Digital Antiquity consortium, hosted at Arizona State University; executive director: Francis McManamon, liaison: ADS, J. Richards (ADS sits on the board of Digital Antiquity)	*Cooperation agreement* Exchange of expertise in data archiving and access
USA	PeriodO: provides a system for publishing cultural periods to link datasets based on unique identifiers; ARIADNE provided dates for periods from the Paleolithic to Modern times for 24 European countries to PeriodO; project lead: Adam Rabinowitz (Institute of Classical Archaeology, UT Austin), liaison AIAC, L. Fentress)	*Cooperation agreement* Publication of cultural period dates for European countries / periods
USA	Corinthian Matters: A resource for the study of the Corinthia, Greece, managed by the Messiah College, Pennsylvania, but multi-authored; project coordinator: prof. David Pettegrew, liaison: AIAC, L. Fentress	Potential integration of data in ARIADNE

[35] ARIADNE (2014-12-08): Collaboration in Mexico, http://www.ariadne-infrastructure.eu/News/ARIADNE-Collaboration-in-Mexico

USA	DARMC - Digital Atlas of Roman and Medieval Civilizations, Harvard University; project director: prof. Michael McCormack, liaison: AIAC, L. Fentress	Potential integration of data in ARIADNE
USA/Greece	American School of Classical Studies in Athens; has digital collections of photographs and other material, e.g. excavations at Corinth and Athens; technical director, Bruce Hartzler, liaison AIAC, L. Fentress	Documentation of major excavations
Algeria	Centre National de Recherche en Archéologie (CNRA): scientific research focused on Algeria, the Greater Maghreb and North Africa; research director: Farid Ighiliriz, liaison AIAC, L. Fentress	Reports/data from excavations (NAHAN project)
Libya	Department of Antiquities, Cyrene: Main focus currently is protection of heritage sites/objects; holds large archives for the Cyrene excavations; director/Cyrene: dr. Ahmed Hussein, liaison AIAC, L. Fentress	Reports/data from excavations (NAHAN project)
Morocco	Institut National des Science de l'Archeologie et du Patrimoine (INSAP), under the Ministry of Culture; INSAP director: prof. Aomar Akerraz, liaison: AIAC, L. Fentress	Reports/data from excavations (NAHAN project)
Tunisia	Institut National du Patrimoine; director: prof. Nabil Kallala, liaison: AIAC, L. Fentress	Reports/data from excavations (NAHAN)

4.1.4 Participation of end-users in project activities

Impact indicator defined in the DoW: At least 400 end-users from the above *[institutional stake-holders from all EU Members States and liaisons with research institutions and initiatives outside Europe]* and other institutions participating in project activities.

More specific and/or additional indicator: The indicator concerns the participation of end-users of ARIADNE in various project activities. The category of end-users includes archaeological and other cultural heritage researchers, practitioners/professionals, data managers (projects, repositories), and others. End-users from the institutions mentioned in the sections above as well as other organisations and initiatives are considered.

Project activity	***Activity & end-users***	***Number of participants***
User needs and requirements survey - 1	International online survey of researchers and directors of research institutions (total sample: 790; 640 with substantial input). The survey results are presented in the First Report on Users' Needs (ARIADNE 2014a).	640
User needs and requirements survey – 2	International online survey of data repository managers (total sample: 91; 52 with substantial input). The survey results are presented in the First Report on Users' Needs (ARIADNE 2014a).	52
Conference sessions and	67 events (co-)organised by ARIADNE	3180

workshops (co-)organised by ARIADNE partners	partners and meetings with representatives of institutions and projects to liaise and establish or advance cooperation; events/meetings with at least 1 presentation by a partner, in most cases more (see *Section 4.2.2*).	
Other conference sessions and workshops	151 other events attended by ARIADNE partners, with at least 1 presentation by a partner (see *Section 4.2.2*).	9621
Transnational access (TNA) study visits and training	Study visits and training of mostly young researchers, dataset/database creators and managers at ARIADNE competence centres; attendees of 10 summer/winter schools and individual visits of one week (see *Section 4.3.2*).	97
Other training provided (e.g. tutorials and short training courses at events)	In addition to trans-national access (TNA) study visits ARIADNE partners provided 18 other training opportunities. Not included is local training by partners except it involved participants from other countries and/or trainers of other partners (see *Section 4.3.3*).	424
Total		**14,014**

The figure of 14,014 is the sum of all project-external participants of ARIADNE needs & requirements surveys, training activities, and sessions and individual presentations at sector conferences, workshops, etc.; partners were not included in the reported number of participants. But we assume that the total number includes 25% participation of people in more than one activity.

ARIADNE thus reached and involved about 10,500 researchers, practitioners, students and other people active or interested in archaeological and cultural heritage research and dissemination, particularly with digital content/data, tools and services (the target was "at least 400 end-users"). Except of the online user surveys all others where direct, face to face activities. But the surveys represent a strong participation as the respondents took the time filling an extensive questionnaire on their data-related practices and requirements.

The number of end-users who participated in ARIADNE surveys, study visits and other trainings, and events (co-)organised by partners or where they gave presentations (10,500) is 30 times larger than the membership of the CAA (350), 5 times larger than the membership of the EAA (2000+), and about 32% of the number of archaeologists working in Europe (33.000; DISCO estimate).

Annex C documents all reported activities. Not included are activities of the ARIADNE Special Interest Groups[36]. These involved members of the ARIADNE partner organisations and institutions reported in *Section 4.1.2*. A larger number of researchers of the latter participated in the excavation data management and data archiving surveys of the Excavation & Monument Data SIG (ARIADNE 2015e and 2016h) and the ARIADNE Expert Forums on the future of digital archaeology of the Archaeological Research Practices & Methods SIG (ARIADNE 2015f and 2016g).

[36] ARIADNE Special Interest Groups, http://www.ariadne-infrastructure.eu/Community/Special-Interest-Groups

4.1.5 Innovation agenda & action plan and sustainability plan

Impact indicators defined in the DoW:

- Innovation Agenda and Action Plan endorsed, published and put into practice by the members of the consortium and affiliated institutions.
- Business Model evaluated by external experts and supported by the members of the consortium and affiliated institutions.

The ARIADNE Innovation Agenda and Action Plan provides a comprehensive set of focus areas and suggested activities on how to advance open access digital archaeology in Europe over the next 5-10 years (ARIADNE 2015b and 2016a). Given the broad range of the agenda the members of the ARIADNE consortium and affiliated institutions have not been asked to endorse it. This would have been inappropriate as the institutions have different missions and activities. Instead members of the institutions are invited to join the not-for-profit ARIADNE Association that has been formally established in November 2016. The membership is on an individual and not institutional basis, because it is often difficult for institutions, especially large public ones, to participate in such an organisation. The ARIADNE Association focuses on continuing the activities of the EU-funded ARIADNE project based on the Sustainability / Business Plan (ARIADNE 2016a: section 4.7). The plan includes further community networking, continuation of TNA training as well as research liaisons established during ARIADNE. Furthermore, the Association will seek opportunities to extend the ARIADNE facilities (Registry/Portal) with new datasets and functionality. The facilities are maintained "in-kind" by the largest ARIADNE partner.

4.1.6 Summary of results

ARIADNE has achieved a strong *community building for innovation* in data-related practices through cooperation agreements, liaisons and informal cooperation with archaeological and other cultural heritage institutions in Europe and beyond. Building on the extensive partnership of the project many institutions, projects and individuals have been mobilised and involved in various project activities, for example, the identification of needs and requirements in e-infrastructure and data services, conference sessions and workshops on ARIADNE topics, training courses, among others. Awareness of the importance of sharing data through research infrastructures has been raised and a community of organisations that engage in data sharing has emerged. Also initiatives for new infrastructures such as national digital archives for archaeological data have been encouraged (see *Section 5.2.2*). Joint ownership of the ARIADNE e-infrastructure and services has been fostered.

Involvement of archaeological and cultural heritage institutions in Europe

ARIADNE set out to involve institutional stakeholders of all EU Member States, particularly European antiquity/heritage authorities, archaeological and other heritage research centres, university departments/institutes, and research and professional associations; the category does not include technological research & development organisations.

The project involved 65 European institutions of which at least one, often more institutions are present of 24 of the 28 EU Member States and two other European countries (Iceland, Norway); the figure includes 17 ARIADNE partners in the relevant categories.

Yet to be involved in the ARIADNE initiative are archaeological institutions in Croatia, Latvia, Luxembourg and Slovakia. These countries have relatively small numbers of archaeologists, i.e. 60 in Latvia or over 200 in Slovakia, compared to over 800 in Portugal or Romania, or over 4000 in Germany or Italy (cf. DISCO 2014: 18).

The institutional stakeholders have been involved based on formal cooperation agreements (15) and through liaison and cooperation on an informal basis. These mostly concerned the building and sharing of databases, use of common vocabularies (e.g. thesauri), and expertise in special subject matters (i.e. digital archiving, scientific datasets, application of the CIDOC-CRM ontology). Institutions also sent researchers to participate in ARIADNE Transnational Access (TNA) trainings for institutional projects (i.e. in view to provide data to ARIADNE).

Cooperation with European archaeology and cultural heritage projects

During the project period ARIADNE cooperated with 10 European projects on an informal or formal basis (e.g. Memorandum of Understanding). Among these EU funded projects for example are ArchaeoLandscapes, CENDARI (e-infrastructure for European history archives), DARIAH (digital humanities), EUROPEANA (Europeana Research), NEARCH (public archaeology), PARTHENOS (humanities e-infrastructures cluster), and the new ESFRI initiative E-RIHS (heritage sciences).

The cooperation topics include common policies and interoperability of e-infrastructures, heritage sciences (with focus on tangible heritage), specific datasets/content archives and standards, and tools/services needed by researchers in the digital humanities, including e-archaeology. Furthermore, public archaeology (NEARCH project) and skills development in an area not covered by ARIADNE trainings: remote surveying techniques and data (ArchaeoLandscapes project).

Particularly noteworthy with regard to the co-ordinated evolution of research e-infrastructures are foreseen joint dataset registration and access services for humanities, archaeology and heritage sciences data, i.e. harmonization of data catalogues following and extending the model developed by ARIADNE.

Involvement of institutions outside Europe and international initiatives

ARIADNE established liaisons and collaborative activities with 19 institutions outside of Europe and international projects; formal cooperation agreements have been signed with 6 institutions/ projects. The spectrum of institutions and projects ranges from national and international authorities (i.e. Israel Antiquities Authority, ICCROM) to special interest groups (i.e. CAA Linked Data SIG) and specific data and vocabulary resources (i.e. PeriodO).

Most liaisons focused on sharing of reports and datasets from archaeological surveys, excavations and conservation projects (i.e. American School of Classical Studies in Athens, ICCROM, MAGIS - Mediterranean Archaeology GIS); exchange of expertise in data archiving and access (i.e. Open Context and tDAR in the United States), and use of common vocabularies and data linking based on W3C recommended Linked Data standards (i.e. Nomisma, Pelagios, PeriodO).

Collaborative activities have achieved important results for advancing data sharing and integration in Europe and beyond. For example, the circulation of archiving expertise has been increased in dedicated events involving Open Context, tDAR and European digital archive providers (see *Section 5.2.2*). With regard to data linking the collaboration with PeriodO merits to be highlighted. Through the PeriodO system ARIADNE made available a set of cultural periods for over 20 European countries with unique identifiers (URIs). These allow stable linking and integration of data and are now available also for other projects in Europe and beyond.

Participation of end-users in project activities

Many more potential end-users of ARIADNE results than expected participated in project activities. Instead of a few hundred end-users 10,500 participated in project activities. This figure does not include people reached through online dissemination of project results.

A large number of end-users (692) participated in the user needs & requirements surveys. The surveys allowed the project gain a good understanding of user needs and expectations from the ARIADNE e-infrastructure and services, which have been developed accordingly. 521 researchers and practitioners benefited from transnational access (TNA) study visits at ARIADNE competence centres (summer schools and individual visits) and tutorials and short training courses at various events. In 67 conference sessions and workshops (co-)organised by ARIADNE partners presented and discussed with participants on-going work and results of the project, with a total of 3180 project external participants reported by partners. Others learned about ARIADNE's work and achievements through individual presentations of partners at 151 other international and national events, with a total of 9621 participants reported.

These figures amount to 14,014 people reached and involved by ARIADNE in surveys, TNA study visits and other trainings, and presentations and discussion of project results at various events. However, we assume that this number includes 25% participation of people in more than one activity. Therefore we estimate that ARIADNE reached and involved about 10,500 researchers, practitioners, students, and others. According to the types of activities these were people active or interested in archaeological and cultural heritage research and dissemination, particularly with digital content/data, tools and services.

Innovation Agenda & Action Plan and Sustainability Plan

The ARIADNE Innovation Agenda and Action Plan provides a comprehensive set of focus areas and suggested activities on how to advance open access digital archaeology in Europe over the next 5-10 years (ARIADNE 2015b and 2016a). In the 5-year horizon it covers Research e-infrastructures services, tools and other resources, Data archiving and curation, Open data sharing and re-use, and Capacity building for open access digital archaeology. Furthermore, in the 10-year innovation horizon, several other potential advances towards innovative digital archaeology are suggested.

Given the broad range of the Innovation Agenda and Action Plan the institutional members of the ARIADNE consortium and affiliated institutions have not been asked to endorse it. This would have been inappropriate as the institutions have different missions and activities (e.g. research & development, data archiving and sharing, education and training). Instead members of the institutions are invited to join the not-for-profit ARIADNE Association that has been formally established in November 2016. The membership is on an individual and not institutional basis, because it is often difficult for institutions, especially large public ones, to participate in such an organisation.

The ARIADNE Association focuses on continuing the activities of the EU-funded ARIADNE project based on the Sustainability Plan (ARIADNE 2016a, section 4.7). The planned activities include further community networking (i.e. meetings at international conferences), continuation of TNA training (provided "in-kind" by ARIADNE competence centres) and research liaisons established during ARIADNE. Furthermore, the Association will seek opportunities to extend the ARIADNE Registry and Portal with new datasets and additional services. The basic operation of the facilities will be maintained by the largest ARIADNE partner CNR "in-kind" (at least for 5 years). The ARIADNE Registry and Portal will be extended with additional datasets and functionality if new funds can be acquired.

4.2 Dissemination of information and guides to good practice

4.2.1 Brief description

The indicators for the dissemination activities concern the reach of the project website and social media, the dissemination of information material, and access to guides to good practice which support skills development. These indicators mainly relate to work package 4, "Good practices and dissemination", which also supported other work packages in engaging the target communities, promoting awareness of project activities and uptake of results.

In the project's Description of Work the following impact indicators have been defined with regard to dissemination activities:

- Project website consulted by at least 12,000 visitors
- Audience of 3000 reached with information material (folders, project announcements, etc.).
- 1500 copies of Good Practice guides distributed or downloaded from the project website

A target for events such as conference sessions and workshops was not defined in the DoW. But figures for this essential activity are also reported in the detailed record of achievements below.

4.2.2 Event organisation and participation

Impact indicator defined in the DoW: In the DoW no indicator for events has been included although a task in WP Dissemination (Task 4.3) concerned the central organisation of the presence of ARIADNE at international events (e.g. dedicated conference sessions), and support of partners for others (e.g. national events or special workshops) and even single presentations, if necessary.

The table below gives an overview of the conference sessions and workshops (co-)organised by ARIADNE partners, including meetings dedicated to establish or advance cooperation with institutions and projects. Furthermore not (co-)organised conference sessions, workshops etc. are included which partners attended and where they gave at least one presentation. Not included are the Transnational Access (TNA) study visits at ARIADNE competence centres and short training courses and tutorials, which are reported in *Section 4.3*.

Detailed and/or additional indicators	***Amount***	***Participants***
○ Events (co-)organised by ARIADNE partners (conference sessions, workshops, round tables) and meetings with representatives of institutions and projects to liaise and establish or advance cooperation; events/meetings with at least one presentation by a partner (in most cases more).	67	3180
○ Other conferences, workshops, etc. attended, with at least one presentation by a partner	151	9621
Total	**218**	**12,801**

The number of 12,801 is the total of project-external participants of (co-)organised conference sessions, workshops, meetings and individual presentations at events reported by project partners. However, we assume that the total includes 25% participation of people in more than one event, hence give a more conservative estimate of 9600.

The events mainly concerned (1) Archaeology and cultural heritage (non-digital focus), (2) Digital archaeology, heritage and humanities events, and (3) E-Infrastructures (archaeology, heritage

sciences, humanities). Furthermore there were a number of events ranging from meetings with high-level officials to events involving schools in archaeological activities. Below we list a selection of events in the categories one to three. The focus is on exemplary events at the international and national/regional levels (the list of all events is included in *Annex C*).

(1) Archaeology and cultural heritage events (non-digital focus)

Characteristics: These events were for researchers and practitioners in archaeology and cultural heritage, including the large international and national events as well as smaller regional and specialised workshops and meetings. Participants were generally interested in digital technologies, but they do not develop digital tools and services, and typically are not "lead-users" (users who adopt, trial and promote new solutions first). At the large events such as the annual meetings of the European Association of Archaeologist only few sessions were about digital technologies specifically.

ARIADNE objective: At such events ARIADNE partners presented the goals, work and results of ARIADNE, informed participants about opportunities offered by the project, and promoted data sharing and access through digital archives and integrating e-infrastructure and services in general.

Events (selection): European Archaeological Council (EAC) - Annual Meeting & Heritage Management Symposium (2014-2016), European Association of Archaeologists (EAA) - Annual Meeting (2013-2016), Society for American Archaeology (SAA) - Annual Meeting (2014-2016), Archaeological Institute of America - Annual Meeting (2014, 2016), International Congress on the Archaeology of the Ancient Near East (Vienna 2016), Roman Archaeology Conference (Rome 2016), Mediterranean Exchange of Archaeological Tourism (Paestum/Italy 2014), International Congress of Classical Archaeology (Merida/Spain 2013), International Conference on Archaeological Prospection (Vienna 2013); various national conferences, for example, Deutscher Archäologiekongress (Berlin 2014), Institute for Archaeologists - Annual Conference (Glasgow/UK 2014), Netherlands Cultural Heritage Agency Symposium (Amersfoort/NL 2014), National Archaeological Conference (Sandanski/Bulgaria 2014), Arheologija v letu 2013 (Ljubljana/Slovenia 2013).

(2) Digital archaeology, heritage and humanities events

Characteristics: These events were for researchers and practitioners in ICT for archaeology, cultural heritage and other humanities, again events of different sizes, but the large ones are considerable smaller than such events of category (1), except the core Digital Humanities - DH conference of the digital humanities community. Participants develop or are "lead-users" (def. see above) of advanced or new digital tools and services.

ARIADNE objective: At such events ARIADNE partners presented the goals, work and results of ARIADNE, networked with other projects and established or enhanced collaborations. Common topics included metadata and vocabularies, data repositories, tools/services for data linking, processing and visualization. A major objective also was strengthening the topic of e-infrastructure in the community.

Events (selection): Computer Applications and Quantitative Methods in Archaeology (CAA) conference (2013-2016), also annual meetings of CAA national chapters (e.g. Germany 2014, Sweden 2013), CIDOC-CRM Special Interest Group meetings (2013-2016), International Conference on Cultural Heritage and New Technologies - CHNT (Vienna 2013, 2016), Colloque MASA 2016 - Mémoires des Archéologues et des Sites Archéologiques (Nanterre, 2016), Digital Heritage International Congress (Marseille 2013, Granada 2015), Digital Archaeology National Conference (Amersfoort/NL 2015), First Cultural Heritage and New Technologies International Congress (Mexico City 2014, delegates from different South American countries), Digital Heritage, Denmark (Aarhus 2015), Digital Heritage, UK (York 2013), Opening the Past - MAPPA Conference (Pisa 2013), Cultural Heritage Creative Tools and Archives – CHCTA (Copenhagen 2013), Congreso Internacional de la

Sociedad de Humanidades Digitales Hispánicas - HDH (Madrid 2015), Digital Humanities - DH (Lausanne 2014); digital libraries, metadata and preservation of digital objects (JCDL 2013, TPDL 2013, 2015, MTSR 2013, iPRES 2013); cultural heritage linked open data: Linked Pasts – Pelagios Colloquium (King's College London 2015), Accesso aperto al patrimonio culturale digitale e linked open data: strategie, progetti e nuove opportunità (Rome 2015); conferences and workshops of various projects, for example, Europeana Network of Ancient Greek and Latin Epigraphy - EAGLE (Nicosia 2015), Digital Cultural Heritage Roadmap for Preservation - DCH-RP (Rome 2014), ArchaeoLandscapes Europe - ArcLand (Amersfoort/NL 2013).

(3) E-infrastructure events (archaeology, heritage sciences, humanities)

Characteristics: These were mainly international and national level events for developers, providers and institutional users of research e-infrastructure and services and research policy and funding bodies.

ARIADNE objective: At such events project partners presented the progress of the ARIADNE e-infrastructure, networked with other initiatives, and contributed to the coordinated development of established and new e-infrastructures projects for the heritage sciences and humanities (e.g. common policies and standards).

Events (selection): Italian-German Workshop on Technology and Infrastructures for Cultural Heritage (Berlin 2016), Tecnologías e infraestructuras para la investigación en Ciencia del Patrimonio (Mexico City 2016), Les rencontres de la TGIR Huma-Num (Lyon, 2016), European Research Infrastructures for Heritage Science - E-RIHS (Florence 2015), Research Infrastructures and e-Infrastructures for Cultural Heritage (Rome, 2014), International Conference on Research Infrastructures - ICRI (Athens 2014), Danish Humanities Research Infrastructures Meeting (Aarhus 2014), Data Service Infrastructure for the Social Sciences and Humanities (Gothenburg 2013), European Research Infrastructure for the Humanities and Social Sciences (Berlin 2013), Digital Research Infrastructure for the Arts and Humanities - DARIAH workshops in different countries (Denmark 2013, Austria 2013, Greece 2014, Ireland 2015).

Details on events specifically aimed at knowledge exchange, coordination and collaboration in the areas of e-infrastructures and data repositories are given in *Section 5.1* and *Section 5.2*, respectively.

4.2.3 Project website and social media

Impact indicator defined in the DoW: Project website consulted by at least 12,000 visitors.

The project website reached a much higher number of visitors from a wide European and international audience. Social media have not been considered in the impact indicators, although such media play an ever greater role in the dissemination of project information. Indeed, ARIADNE achieved a large distribution of project information and recognition through social networks.

Website

Detailed and/or additional indicators	***Results***
○ Website visitors (2/2013-12/2016)	36,611
○ Sessions (2/2013-12/2016)	53,849
○ Page views (2/2013-12/2016)	184,074

At least 12,000 website visitors have been expected, but over 36,000 consulted the project website; also the numbers of sessions and page views are quite high. The website access is described in great detail in a project report (ARIADNE 2017a), here we give a brief summary of the visitor traffic.

Analysis of the visitor traffic across the four years of the project shows a steady increase in the numbers of visitors, sessions and page views in each of the first three years. After the launch of the ARIADNE data portal, formally on the 30th of March 2016, there was a slight decline in traffic. The web statistics show that the ARIADNE website has a European and international user base. About 75% of the visitors were located in Europe. Looking at the percentage of visits by country, the top European countries are: Italy (16.72%), UK (13.17%), Germany (6.76%), Greece (6.74%), France (5.52%), Austria (3.82%), Netherlands (3.63%), Spain (2.96%) and Ireland (2.21%). Visits from other countries such as Belgium, Bulgaria, Cyprus, Hungary, Slovenia and Sweden are also well over 1% percent. About 1% was visits from Russia. With regard to other world regions, of the total number of visits there were 6% from the United States of America, 2% from Brazil, 2% from South Korea and 1% from India

Social media

Social media have not been considered in the impact indicators. However, ARIADNE achieved a large distribution of project information and recognition through social networks:

Social Media – Detailed and/or additional indicators	***Results***
○ SlideShare account, set up in July 2014	
- ARIADNE products uploaded by January 2017	91 presentations and 26 documents (e.g. booklets, deliverables, reports)
- Total views of ARIADNE products	69,270 views, 36,165 over the last twelve months
○ Twitter: @Ariadne_Network, set up in April 2013	
- Followers (31/12/2016)	754
- Following (31/12/2016)	361
- Tweets since April 2013	1882 (772 during 2016)
- Re-tweeted ARIADNE tweets	443 retweeted (23.5%) in total 1140 times
- Mentions of ARIADNE by users throughout the project	787 times by 170 users; on average 0.7 times per day
○ ARIADNE LinkedIn group	39 members, 29 discussions
○ ARIADNE Facebook group (mainly used to post news and photographs from ARIADNE events)	21 members
○ Total reach of ARIADNE's social networks	In total about 11,500 members with a reach of around 160,000 followers (conservative estimate).

ARIADNE did not create a project account on YouTube but a number of ARIADNE related videos have been uploaded by partners. A larger number of video recordings of presentations given by ARIADNE partners at CAA and EAA conferences have been produced by Recording Archaeology (Doug Rocks-Macqueen) who published them on YouTube and have been accessed by a wider audience. Further details on ARIADNE social media based dissemination are given in the final report on project dissemination (ARIADNE 2017a).

4.2.4 Information material

Impact indicator defined in the DoW: Audience of 3000 reached with information material (folders, project announcements, etc.).

The project has disseminated a set of information material which includes project booklets, newsletters, posters, leaflets and flyers. All material except the newsletter has been disseminated in physical and digital form. The newsletter has been posted on the project website and mailed to subscribers.

The dissemination in print and digital form certainly reached an audience of over 3000. For example, the first project booklet *ARIADNE - The Way Forward to Digital Archaeology in Europe* since December 2014 received over 6500 views on the ARIADNE SlideShare account. The *ARIADNE Introduction* presentation received over 3500 views. Figures on a number of other presentations (not basic project information) are given in *Section 4.2.6*.

The set of project dissemination materials has been maintained and some products have been updated:

- Project booklet: *ARIADNE - The Way Forward to Digital Archaeology in Europe* (97 pages), first distributed as print copies at the Research Infrastructures and e-Infrastructures for Digital Cultural Heritage Conference, Rome, 13-14 November 2014 (about 200 participants); the most popular product on ARIADNE SlideShare (over 6500 views since 12/2014);
- Project booklet: *ARIADNE – Building a Research Infrastructure for Digital Archaeology in Europe* (63 pages) first distributed as print copies at the final project event in Florence in December 2016 (about 120 participants);
- Project leaflet in two editions (2013, 2016), distributed by partners at international and national events (i.e. CAA, EAA, CHNT) and online;
- Flyers to advertise trainings and products: i.e. calls for TNA study visits, presentation of available tools and services, distributed by partners at events and online;
- Over 150 project news and announcements disseminated via the project website;
- Periodic project newsletters (9 issues), published online and disseminated to 410 subscribers.

We assume that the online dissemination reached a wider audience than the printed products. But the edited products have been appreciated, especially the booklets which give an overview of ARIADNE's goals, activities and results.

4.2.5 Guides to good practice

Impact indicator defined in the DoW: 1500 copies of Good Practice guides distributed or downloaded from the project website.

More specific and/or additional indicator: The indicator concerns Guides to Good Practice in the creation and dissemination of archaeological data. The guides are accessible on the website of the Archaeology Data Service (ADS)[37] and promoted by ARIADNE. The project has also initiated and supported the development of new and extension/updates of existing guides as well as thematic case studies.

[37] Archaeology Data Service (ADS) & Digital Antiquity: Guides to Good Practice, http://guides.archaeologydataservice.ac.uk

Detailed and/or additional indicators	***Results***
○ New guides and case studies produced with ARIADNE support	3 new guides 3 new case studies
○ Extension/updates of guides with ARIADNE support	1 guide (former Virtual Reality guide) extended with content to form the new 3D Guide
○ ARIADNE sponsored guides and case studies viewed on the website of the Archaeology Data Service	In total about 2000 unique page views

Guides and case studies produced with ARIADNE support:

- *Selection and Retention of Files in Big Data Collections: The Example of the Pergamon Excavation of the DAI Istanbul* (case study published in August 2013)[38]: The case study looks into "big data collections" created through long, multi-phased and multi-disciplinary processes of generating, transforming and finalizing data; the study addresses two basic questions: the selection of data from large datasets, and the best way to document such datasets so that the processes, relationships, and dependencies can be easily understood; the case study has been contributed primarily by DAI and authored by Felix Schäfer (DAI).
- *Dendrochronological Data in Archaeology* (guide published in June 2015)[39]: The guide addresses the need to provide guidance for the production, documentation, and storage of dendro-chronological datasets and incorporates existing good practice developed by organisations in the Netherlands and the United States, specifically the Tree Ring Data Standard (TRiDaS). The guide has been contributed by DANS and authored by Esther Jansma (Cultural Heritage Agency and Utrecht University, The Netherlands) and Peter Brewer (Laboratory of Tree-Ring Research, University of Arizona).
- *The Dendrochronology of the Early-medieval Emporium Dorestad, Netherlands* (case study published in June 2016)[40]; the case study provides a worked example of the reanalysis of dendrochronological data using the Tree Ring Data Standard (TRiDaS) and associated tools; the case study has been contributed by DANS and authored by Esther Jansma (Cultural Heritage Agency and Utrecht University, The Netherlands).
- *3D Datasets in Archaeology* (guide published in August 2016)[41]: The guide addresses the need to provide guidance for the production, documentation, and storage of 3D datasets, specifically 3D models, and is designed to complement and align with existing Guides focused on data creation and digitisation, specifically those on Laser Scanning, Photogrammetry, CAD, and Structured Light Scanning. Additionally, the 3D guide incorporates and aligns with existing good practice guides developed by the 3D-ICONS project and refers to this project's work on data creation pipelines.

[38] Schäfer, Felix: Selection and Retention of Files in Big Data Collections: The Example of the Pergamon Excavation of the DAI Istanbul. Archaeology Data Service / Digital Antiquity: Guides to Good Practice (August 2013), http://guides.archaeologydataservice.ac.uk/g2gp/CS_ARIADNE-DAI-Schafer

[39] Brewer P. & Jansma E.: Dendrochronological Data in Archaeology: A Guide to Good Practice (June 2015), http://guides.archaeologydataservice.ac.uk/g2gp/Dendro_Toc

[40] Brewer P. & Jansma E.: The Dendrochronology of the Early-medieval Emporium Dorestad, Netherlands (July 2016), http://guides.archaeologydataservice.ac.uk/g2gp/Dendro_CS

[41] Trognitz M., Niven K., Gilissen V. *et al.*: 3D Models in Archaeology: A Guide to Good Practice (November 2016), http://guides.archaeologydataservice.ac.uk/g2gp/3d_Toc

The guide has been contributed primarily by DAI in collaboration with ADS and DANS and authored by Martina Trognitz (IANUS, DAI), Kieron Niven (ADS), and Valentijn Gilissen (DANS).

- *Thermoluminescence Dating* (guide published in January 2017)[42]: The guide addresses key elements of thermoluminescence measurements and determination of the age of archaeological materials which should be documented and described with appropriate metadata. The guide has been contributed by ATHENA-CETI (Xanthi, Greece) and authored by Nikolaos A. Kazakis and Nestor C. Tsirliganis.
- *3D Datasets in Archaeology: Structure from Motion* (case study in preparation by DAI researchers for publication during 2017): The case study complements the existing 3D guidelines through the illustration of data creation and documentation, including metadata, using an exemplary dataset.
- *Reflectance Transformation Images (RTI) Datasets* (guide in preparation by ADS and DAI for publication during 2017): The guide focuses on the documentation and preservation of RTI datasets; it incorporates current guidelines for data acquisition and processing produced by Cultural Heritage Imaging (CHI) and Historic England, and extends this to include data selection, preservation and documentation considerations.

In addition to the guides and case studies addressed above, ADS hosts the wiki-based guide to good practice in archiving archaeological projects created by the ARCHES project[43]. The guide covers both the material (finds) archive and the documentary archive, which includes born-digital or digitised records such as documents, drawings, photographs, etc. The wiki-based guide is available in English; downloadable versions of the guide are available in Czech, Dutch, English, French, German, Icelandic and Swedish.

4.2.6 Research papers and other project products

Impact indicator defined in the DoW: In the DoW no indicator for publications has been included although bibliometrics was mentioned in the description of Task 2.5 Impact Evaluation. Below we give the number of papers and views of some other products (i.e. conference presentations) made available on SlideShare.

Detailed and/or additional indicators	***Results***
○ Papers published in journals, conference proceedings, books and other publications	86
○ Total views of ARIADNE products on SlideShare: 91 presentations and 26 documents by January 2017	69,270 views, 36,165 over the last twelve months
○ Views of selected products on SlideShare	
- ARIADNE - The Way Forward to Digital Archaeology in Europe (booklet of 97 pages)	6505 views since 16/12/2014
- ARIADNE: First Report on Users' Needs (deliverable)	2089 views since 11/08/2014
- Open Data in Archaeology (presentation)	1586 views since 20/08/2014
- Austrian Archaeological Data and Archiving Options	1446 views since 21/01/2015

[42] Kazakis N.A. & Tsirliganis N.C.: Thermoluminescence Dating: A Guide to Good Practice (January 2017), http://guides.archaeologydataservice.ac.uk/g2gp/TL_Toc

[43] ARCHES - Archaeological Resources in Cultural Heritage: a European Standard (EU Culture Programme, 6/2012-5/2014), http://archaeologydataservice.ac.uk/arches/

- Open Access in Italy (presentation)	1211 views since 26/09/2014
- Open Access of Research Data: the present and future situation in Germany (presentation)	1173 views since 26/09/2014

ARIADNE researchers reported in total 86 project-related publications published in journals, conference proceedings, books and other publications; the list of articles is included in the final report on project dissemination (ARIADNE 2017a). The publications include special journal issues and proceedings on ARIADNE topics such as Open Access & Open Data (Archäologische Informationen, Vol.38/2015, in English), CIDOC-CRM extension and application (EMF-CRM Workshop 2015, CEUR-WS/Vol.1656), and Research E-Infrastructures. Among the latest publications is a multi-authored paper on the ARIADNE e-infrastructure in a special issue of the Journal on Computing and Cultural Heritage, edited by leading researchers of the project. Also particularly noteworthy is the paper *Enabling European Archaeological Research: The ARIADNE E-Infrastructure* in the proceedings of the European Archaeological Council - Symposium 2016 published in the e-journal Internet Archaeology.

4.2.7 Summary of results

Events organisation and participation

ARIADNE partners presented the project work and results and networked with participants at 218 events, with a total of 12,801 participants. The events were conferences and workshops in three categories: events for researchers, practitioners, students in the field of archaeology and cultural heritage (non-digital focus); for researchers, developers and advanced users in digital archaeology, heritage and humanities; and for developers/providers and institutional users of research e-infrastructure as well as research policy and funding bodies. Furthermore there were a number of events ranging from meetings with high-level officials to events involving schools in archaeological activities.

67 of the events were (co-)organised sessions or workshops at conferences and special meetings with representatives of institutions and projects to liaise and establish or advance cooperation (3180 participants). Furthermore partners presented ARIADNE and their project contributions at 151 other events (9621 participants). Not included in these figures are transnational summer schools and short training courses and tutorials.

The number of 12,801 is the total of project external participants of (co-)organised conference sessions, workshops, meetings and individual presentations at other events reported by project partners. We assume that the total includes 25% participation of people in more than one event. Thus the estimated total participation is 9600.

Project website and social media

Project website: At least 12,000 website visitors have been expected (indicator of success), but over 36,000 consulted the project website; also the numbers of sessions (about 54,000) and page views (184,000) are quite high. The web statistics show that the ARIADNE website has a European and international user base; about 75% of the visitors were located in Europe.

Social media: Such media have not been considered in the impact indicators, although they play an ever greater role in the dissemination of project information. Indeed, ARIADNE achieved a large distribution of project information and recognition through social media platforms (SlideShare, Twitter). ARIADNE has a Twitter account since April 2013 and at present 754 followers. Of 1882 ARIADNE tweets 443 (23.5%) have been re-tweeted in total 1140 times. There have been 787

mentions of ARIADNE by 170 Twitter users. ARIADNE's social networks have about 11,500 members with a total reach of 160,000 followers (conservative estimate). SlideShare results are given below.

Dissemination of information material

The project has disseminated a set of information material which includes project booklets, newsletters, posters, leaflets and flyers. All material except the newsletters has been disseminated in physical and digital form. An audience of 3000 was expected (indicator of success), which certainly has been surpassed. For example, the first project booklet *ARIADNE - The Way Forward to Digital Archaeology in Europe* since December 2014 received over 6500 views on the ARIADNE SlideShare account, the *ARIADNE Introduction* presentation over 3500 views.

Over 150 project news and announcements have been disseminated online. These include the periodic project newsletters (9 issues), published online and disseminated to 410 subscribers. Two project booklets have been produced and disseminated at conferences and online: *ARIADNE - The Way Forward to Digital Archaeology in Europe* (97 pages) and *ARIADNE – Building a Research Infrastructure for Digital Archaeology in Europe* (63 pages). Other edited print and online products included: a project leaflet in two editions (2013, 2016), and flyers to advertise trainings and products: i.e. calls for TNA study visits, presentation of available tools and services. These have been disseminated at international and national events (i.e. CAA, EAA, CHNT) as well as online.

Guides to good practice

ARIADNE has promoted good practices in the creation, documentation and archiving of archaeological datasets. The project has initiated and supported the development of four guides to good practice and three case studies. These already are or will shortly be accessible in the online *Guides to Good Practice* of Archaeology Data Service & Digital Antiquity. The guides concern 3D Datasets, Reflectance Transformation Images (RTI) Datasets, Dendrochronological Data, and Thermoluminescence Dating; one case study addresses the selection and documentation of datasets of "big data collections" and two others complement the 3D and Dendrochronology guides with real-world worked examples. Between August 2013 and January 2017 the already published guides and case studies received about 2000 unique page views. So far the most accessed is the Dendro-chronology Data guide (published in June 2015) with 1275 unique page views; however the 3D Datasets guide, published in December 2016, already has had over 400 unique page views.

Research publications and other products

ARIADNE researchers reported in total 86 project-related articles published in journals, conference proceedings, books and other publications; the list of articles is included in the final report on project dissemination (ARIADNE 2017a). The publications include special journal issues and proceedings on ARIADNE topics such as Open Access & Open Data (Archäologische Informationen, Vol.38/2015, in English), CIDOC-CRM extension and application (EMF-CRM Workshop 2015, CEUR-WS/Vol.1656), and Research E-Infrastructures.

Among the latest publications is a multi-authored paper on the ARIADNE e-infrastructure (Meghini *et al*. 2017) in a special issue of the Journal on Computing and Cultural Heritage, edited by leading researchers of the project. Also particularly noteworthy is the paper *Enabling European Archaeological Research: The ARIADNE E-Infrastructure* in the proceedings of the European Archaeological Council - Symposium 2016 published in the e-journal Internet Archaeology (Aloia *et al*. 2017).

Other ARIADNE products have been made available on SlideShare, which proved to be a very effective dissemination method. By January 2017 in total 91 presentations and 26 documents (i.e.

deliverables) have been uploaded on SlideShare. These products received in total 69,270 views; 36,165 over the last twelve months.

4.3 Transnational study visits and training

The impacts of transnational access (TNA) activities concern study visits and training of mostly young researchers at ARIADNE competence centres, and online access to services provided by research infrastructures (e.g. digital archives). This section centres on the study visits and training at ARIADNE centres and other training provided such as tutorials at conferences.

4.3.1 Brief description

Researchers have been offered the opportunity to visit competence centres of project partners to be trained and guided in the use of novel methods and tools for their specific research questions and data. This support focused on the design and creation of datasets (including work on legacy data)[44], application of the CIDOC Conceptual Reference Model (CIDOC-CRM)[45], and 2D/3D documentation of archaeological sites and objects[46]. Furthermore training has been offered in the form of tutorials at events and short courses at partner sites, for example, training to use tools and services developed by project partners.

4.3.2 TNA study visits

Impact indicators defined in the DoW:

- 300 researchers requested transnational access to RIs [research infrastructures], the majority of which young researchers [defined as graduate students, PhD candidates, or Post-Doc level researchers].
- High benefit of the RI access for their projects confirmed by the visiting researchers.

In the TNA programme three ARIADNE competence centres (Athena RC, CNR-ISTI and PIN) offered transnational access for group visits (summer school format) and individual access visits. The final report on ARIADNE Transnational Access gives a detailed account of the programme (ARIADNE 2017b). Calls for applications for study visits were advertised in 2014, 2015 and 2016. Researchers were asked to bring projects or case studies with focused goals that are technically feasible within the framework of the TNA and the host facility.

A selection committee comprising of experts from both outside to the project consortium and the TNA providers assessed the applications. The main selection criteria were the quality of the applicant, the scientific merit of the case study or individual research project proposed, and the potential of the applicant to benefit from the training on offer, for example by improving their research output or developing local expertise and/or facilities.

Between 2014 and 2016 ARIADNE received 136 applications for TNA visits and, following review by the selection committee, 97 travel bursaries were awarded. A small number of researchers also

[44] Example: Design of Archaeological Datasets Pisa 2016, ISTI-CNR, Pisa, Italy, 4-8 July 2016, http://www.ariadne-infrastructure.eu/index.php/Services/Transnational-Access/2016-TNA-Call/TNA-school-Datasets-Pisa

[45] Example: Summer School on Mapping existing datasets to CIDOC CRM, PIN, Prato, 26-30 May 2014, http://www.ariadne-infrastructure.eu/News/CIDOC-CRM-summer-school

[46] Example: 2D/3D Documentation for Archaeology Summer School, ISTI-CNR, Pisa, 23-27 June 2014, http://www.ariadne-infrastructure.eu/News/2D-3D-Documentation-for-Archaeology-Summer-School

participated in the TNA trainings without receiving a bursary; these researchers visited an ARIADNE competence centre in their own country, which was not eligible for funding.

The majority of TNA participants with bursaries were postgraduate students (52%) and postdoctoral researchers (20%); 15% were expert researchers (professors and other senior researchers), 12% were technicians (ICT) and 2% were undergraduate students. 50% of the participants were female. The participants came from institutions in 23 countries, 21 EU member states plus Serbia and Argentina; thirty different nationalities were represented, 20 EU member states plus Argentina, Australia, Brazil, Canada, China, Iceland, Norway, Serbia, Turkey and USA.

Character of the TNA "training"

The kind of TNA provided within ARIADNE is a combination of research activities and training in a collaborative approach that has emerged as the most effective for participants. Only a small part of the TNA concerns pure training where knowledge transfer goes in one direction, from the trainer to the trainee. The larger part is either shared advancement or goes the other way round, into an improvement of the 'trainer' skills deriving from being exposed to new research questions and looking for their solution. The TNA indeed often triggered new research ideas and improvement of archaeological documentation, especially documentation based on new extensions of the CIDOC-CRM.

The project Flow of Ancient Metal Across Eurasia (FLAME), carried out by the Research Laboratory for Archaeology and the History of Art (RLAHA) at the University of Oxford and funded by the European Research Council, can serve as an example. The FLAME project investigates the movement, exchange, and transformation of metal in Eurasian societies during the Bronze and Early Iron Age. Researchers of the laboratory participated in the TNA with the goal to define a CIDOC-CRM based semantic system for integrating the scientific databases of the project (i.e. chemical and isotope analyses of copper alloy and of radiocarbon-dated archaeological contexts). The joint research and development activities in the TNA focused on the definition of a model which represents the analytical process at the intersection of archaeological and scientific studies. The result was an improved interconnection between the CIDOC-CRM extensions for archaeological excavations (CRMarchaeo) and scientific observations (CRMsci). Similarly, joined work on a TNA project aimed to create a digital edition of the Louvre collection of Greek Epigraphic Inscriptions inspired the definition of a new set of CRM classes specifically tailored for epigraphy, and to lay the basis for the development a CRM epigraphic extension.

Feedback on benefits of TNA participants

Participants had to fill the "Research Infrastructures: User group questionnaire" provided by the Community Research and Development Information Service (CORDIS)[47], and an additional questionnaire produced by the ARIADNE TNA management. The ARIADNE questionnaire asked TNA participants about achievements experienced during the study visit or summer school and suggestions for improvements of the training. Copies of both questionnaires filled by participants are archived in the internal documentation of the project.

The feedback from the participants was very positive. Everyone felt that they had learned a lot during their week and that in many cases the new knowledge will help with the development of their personal research projects. The hands-on experience (working with tools and with data) and practical help and advice on their research projects were particularly valued. Also the organisation, logistics

[47] CORDIS: Research Infrastructures: User group questionnaire http://cordis.europa.eu/fp7/capacities/questionnaire_en.html

and trainers of the TNA offer were appreciated very much. The main potential improvement mentioned by several participants was the wish for longer training courses (more than one week).

Below we give some examples of feedback from participants[48]:

"The course gave me a very good overview on how metadata can be organized, and suggested some good tools that can help me in carry out my project. I also got in contact with other people in the field that share my problems with metadata management, and we will have the possibility to share our future experience and solutions" – Carlotta Capurro (Belgium).

"The main achievements experienced during the summer school are related to the possibility to manage and handle 3D models from pictures: this means that in a very short time it would be possible to document archaeological features, and share them very easily" - Paola Derudas (Italy).

"I studied different approaches and during the summer school I carried out several practical tests using these methods and techniques to implement these into the 3D/2D documentation work-flow and to achieve better results" – Andres Uueni (Estonia).

"My main achievement experienced at the summer school was that I began to understand not just how to use the equipment and software, but also how they worked and the benefits of different types of technology. This was very useful for me, as I have often worked alongside people using different methods of 3D recording, but never actually completed it myself; I now feel that I have the knowledge and understanding to undertake this type of work myself" – Michael A. Bevivino (Ireland).

"Understanding fundamentals of ontology, CIDOC-CRM ontology standards by given theoretical and practical examples. Mapping existing data model of ArAr laboratory with using Mapping Memory Manager open source schema mapping tool. Learning advantage of data integration, semantic web, and graph databases" – Aybuke Ozturk (France).

"An overview about the possibilities and advantages of ontologies for archaeological datasets, especially CIDOC CRM. An understanding about the technical aspects of mark-up languages. Advice on the particular problems I encountered in our project" – Seta Stuhec (Austria).

"I got a complete overview of the semantic web and its different 'components'. The presentation of the CIDOC-CRM and the related case studies clearly stated the problems when looking into archaeological data design. As far as my personal project is concerned, the acquired information is for me a perfect opportunity to look in a different way at my data and the striven data structure, with particular reference to the web-based GIS component of my project" – Michelle Pfeiffer (Germany).

"From the course of this summer school… Now I am able to develop the right project work plan and budgets for the project" – Yuan Yuan (Germany).

"The overall organisation was excellent - logistics were clear and easy to follow and the course instructors were knowledgeable and engaging" – Martin Duffy (Ireland).

"This was one of the best organisations I have experienced and when I left home, I had already all the data about how and where to reach to CNR. The presentations were very good; the quality of the lectures was top level. Another useful thing is that the presentations are on internet so it can be downloaded. From my point of view the organisation was excellent" – Adela Kovaks (Romania).

[48] See also: ARIADNE: TNA 1st Year Feedback, http://www.ariadne-infrastructure.eu/Services/Transnational-Access/TNA-1st-Year-Feedback; ARIADNE (2015-10-30): Interview with Roberta Zeni on Mapping EpiDoc to CIDOC-CRM, http://www.ariadne-infrastructure.eu/News/Interview-with-Roberta-Zeni-on-Mapping-EpiDoc-to-CIDOC-CRM

"Similar events in the future should last more than one week, if possible. This approach could provide even stronger knowledge exchange and team co-operation, which can be the base of new synergy and scientific research" – Andres Uueni (Estonia).

In summary, the TNA participants acquired new knowledge and skills which they perceived as very useful for their research projects. Also the organisation of the TNA and the opportunity to network and collaborate with other researchers were highly appreciated.

Discussion of TNA in the context of e-infrastructures

The Transnational Access (TNA) study visits/training provided by ARIADNE expertise centres allowed about 100 mostly young researchers to acquire knowledge and skills for their own projects and/or initiatives of their institutions. The feedback on this training offer has been very positive. TNA is a mandatory part of Integrating Activities funded under the EU Research Infrastructures Programme. Therefore ARIADNE developed a TNA programme that best fits with the focus of the project and centred on skills development for researchers.

The focus of ARIADNE has been the implementation of e-infrastructure for archaeological data. One question here is how to optimise and scale TNA training in the context of e-infrastructures. The TNA scheme of the EU Research Infrastructures Programme has been created in the first place for physical access to research facilities such as molecular biology laboratories, synchrotrons, research telescopes, etc. The scheme can be adapted for physical access to expertise centres of e-infrastructures, which include e-infrastructure providers, digital repositories and databases, and research centres with expertise in technologies, datasets and vocabularies that are being used in the domain.

Concerning the target groups of TNA of a core domain e-infrastructure the sizes are: few e-infrastructure managers, many managers of digital repositories/databases, and a large number of domain researchers.

Research Infrastructures: There have been projects for training of staff of large, single-site and distributed physical Research Infrastructures, in particular RAMIRI (2008-2012)[49] and the current RItrain - Research Infrastructures Training Programme project (2015-2019)[50]. There may be a need for similar programmes for managers of research e-infrastructures.

Digital repositories: There are many of these but not for archaeological data. The Directory of Open Access Repositories (OpenDOAR) per 1/2/2017 documents 1489 repositories in Europe of which 126 have a focus on history and archaeology content. These repositories mainly hold documents and visual material, more for historical studies than archaeological research. At present there are not many archaeological *data archives*, including ADS, DANS (E-Depot), IANUS and some existing or planned others, together maybe ten. In addition, and growing in number, there are projects of archaeological research institutes to improve legacy databases and build new ones. These include databases for specific own projects as well as to collect data from many contributors. Examples of these are the FLAME database (see *Section 4.3.2*), the DIME and MEDEA metal-detector finds databases (see *Section 4.1.2*), ZRC-SAZU's ZBIVA database and the MNM Archaeology Archive (see *Section 4.4.3*).

Here we see a clear need of knowledge exchange between projects and offering TNA visits. Building on the experiences of data management training for partners, the ARIADNE data archives and other institutions have submitted an EU COST Action proposal "Saving European Archaeology from the Digital Dark Age - SEADDA" (1/12/2016). The initiative aims to collect, consolidate and transfer best

[49] RAMIRI - Realising and Managing International Research Infrastructures 1+2 projects (11/2008-10/2012), http://www.ramiri.eu; main product: RAMIRI Handbook for RI managers, http://www.ramiri-blog.eu

[50] RItrain - Research Infrastructures Training Programme (EU, H2020, 9/2015-8/2019), http://ritrain.eu

practices in archiving, dissemination and re-use of archaeological data. If this proposed action is selected for funding a substantial increase of knowledge sharing and capacity development across Europe will be possible. Concerning TNA, i.e. visits of managers of new data repositories to leading data archives/centres, the knowledge transfer and skills development of a few managers clearly benefits a large number of repository users.

Individual research projects: The ARIADNE TNA programme offered knowledge and skills development mainly for projects of individual researchers, but also for researchers and IT staff of institutions that aim to enhance or build new databases. The training for the individual researchers focused on the use of 3D and other visual media tools, building state-of-the-art datasets, including use of CIDOC-CRM and other domain vocabularies. Training for institutional projects focused mainly on the latter.

TNA visits of researchers for own projects can benefit only a small number of individuals, it does not scale, and the benefit for the archaeological research community overall is limited. A more flexible, scalable scheme would be preferable. We suggest a hybrid model: Provide *online* TNA courses for many on selected knowledge that is not easily available (e.g. knowledge in CIDOC-CRM and recent extensions). Such courses could be provided as webinars involving acknowledged experts and practitioners. Physical TNA then provide in identified clear cases of benefit for the wider research community. The latter would be high potential projects of individual researchers and data managers as mentioned above. Arguably this is the most flexible and scalable approach, including selection of high potential candidates for TNA study visits.

Related to the above we note current trends in training provision for research data management and data science. General data management training for researchers has been provided by national initiatives as well as a large European project, FOSTER[51]. These are meant to promote awareness and capacity development at universities because only these can train individual "next generation" researchers in data management at large scale. The same concerns "data science" training as currently provided by the European project EDISON[52]. Such training arguably will not be provided by universities but dedicated data science or e-science centres (e.g. Netherlands eScience Center).

In summary we conclude and suggest:

The ARIADNE trans-national access and training offer centred mainly on researchers' skills related to own data, e.g. dataset development, data mapping, special data formats like 3D, etc. Thereby researchers acquired skills in research data creation and management as relevant for archaeological projects. We suggest focusing more on providing training for potential providers of new datasets (i.e. curators of institutional legacy databases and major new projects). In any case to avoid a focus on general data management planning; this should be provided by universities.

Training for data managers of digital archives/repositories is a concern. In the archaeology sector, such professionals may not be readily available, but require capacity building, training and career opportunities. In this regard the ARIADNE training could align with the knowledge transfer for new archaeological data archives (i.e. the SEADDA initiative).

[51] FOSTER - Facilitate Open Science Training for European Research (EU, FP7, CSA, 2/2014-1/2016), http://www.fosteropenscience.eu

[52] EDISON - Education for Data Intensive Science to Open New Science Frontiers (EU, H2020, CSA, 8/2015-7/2017), http://www.edison-project.eu

4.3.3 Other training provided

In addition to trans-national access (TNA) study visits the ARIADNE training programme included tutorials, hands-on workshops and short courses at events and partner sites. This training offer covered topics similar to the study visits, introduced participants to the TNA program, online data resources and new tools and services of ARIADNE partners.

Impact indicator defined in the DoW: 250 users trained in tutorials at events or short training courses on effective RI [research infrastructure] use, the majority young researchers [defined as graduate students, PhD candidates, or Post-Doc level researchers].

Short training courses and tutorial	***Participants***
Delavnica arhiviranja digitalnih podatkov, Ljubljana, Slovenia, 21 January 2016: Data management workshop for archaeologists and heritage professionals, held at ZRC-SAZU with trainers from ADS and PIN	38
Datenmanagement in der Archäologie, Vienna, Austria, 19 January 2016: Data management workshop for archaeologists and heritage professionals, held at ÖAW-OREA with trainers from ADS and PIN	42
CIDOC-CRM Mapping Workshop for Humanities Scholars and Cultural Heritage Professionals, Oxford e-Research Centre, UK, 9-10 Nov. 2015: FORTH-ICS (M. Theodoridou) in cooperation with British Museum (D. Oldman, ResearchSpace)	25
Digital Heritage 2015 conference, Granada, Spain, 28 September 2015: Tutorial "3DHOP - Presenting Online High-res 3D Models: a Crash Course", CNR-ISTI	25
Reconstruction of the Archaeological Landscape through Virtual Reality, Rome, Italy, training school, 8-11 September 2015: Included training on two days on how to use the ARIADNE Landscape Services, CNR-ITABC[53]	21
CAA 2015, Siena, Italy, 30 March 2015: Tutorial "3DHOP - Presenting Online High-res 3D Models: a Crash Course", CNR-ISTI	65
CAA 2015, Siena, Italy, 30 March 2015: Workshop "Reconstructing Ancient Landscape in the Cloud", CNR-ITABC	45
CAA 2015, Siena, Italy, 30 March 2015: Workshop "Hands-on Archaeological Conceptual Modelling 2", CSIC-Incipit	20
SEAHA training course, Pisa, Italy, 22-23 January 2015: PhD students from the University of Brighton visited CNR-ISTI for a training course on visual technologies; the young researchers participate in a programme of SEAHA - Centre for Doctoral Training in Science and Engineering in Arts Heritage and Archaeology (UK)[54]	3
Mediterranean Exchange of Archaeological Tourism, Paestum, Italy, 30 October 2014: "Opportunities within the ARIADNE network", introduced participants to the TNA training offer and online services, Athena-CETI, CNR-ISTI, PIN,	6
EAA 2014, Istanbul, Turkey: ARIADNE workshop, 11 September 2014: "Opportunities within the ARIADNE network", introduced participants to the TNA	9

[53] ARIADNE (2015-11-24): Reconstruction of the Archaeological Landscape through Virtual Reality, http://www.ariadne-infrastructure.eu/News/Landscape-Reconstruction

[54] ARIADNE (2015-01-23): SEAHA research collaboration with CNR-ISTI, http://www.ariadne-infrastructure.eu/News/SEAHA-collaboration; Centre for Doctoral Training in Science and Engineering in Arts Heritage and Archaeology, http://www.seaha-cdt.ac.uk

training offer and online services, Athena-CETI, CNR-ISTI, PIN	
CIDOC Annual Conference 2014: Access and Understanding - Networking in the Digital Era, Dresden, Germany, 7 September 2014: Tutorial on CRMarchaeo and CRMsci, FORTH-ICS	10
EVA 2014, London, UK: ARIADNE workshop, 10 July 2014: "Learning Opportunities for Sharing Data in the ARIADNE Project", introduced participants to the TNA training offer and online services, PIN	5
CAA 2014, Paris, France, 22 April 2014: ARIADNE workshop "Online resources for archaeological research", introduced archaeological researchers to ARIADNE online data resources; ADS, Arachne (DAI) and Fasti Online (AIAC); also the director of tDAR - The Digital Archaeological Record (USA) gave a presentation	20
CAA 2014, Paris, France, 22 April 2014: Workshop "Hands-on Archaeological Conceptual Modelling 2", CSIC-Incipit	20
International Summer School "UAVs applied to Cultural Heritage and Archaeology", Certosa, Pontignano, Italy, 20-26 September 2013: Presentations by CNR-ITABC	30
EAA 2013: Pilsen, Czech Republic, 4 September 2013: ARIADNE workshop "Data Management Planning and Online Resources for Archaeology"[55]; centred on strategies for effective data management and planning (ADS, SRFG) and online data resources available to researchers through ARIADNE (ADS, DAI [Arachne], AIAC [Fasti Online], KNAW-DANS [E-Depot] and SND [digital archive])	25
CAA 2013, Perth, Australia, 25 March 2013: Workshop "Hands-on Archaeological Conceptual Modelling (HACMod)", C. Gonzalez-Perez of ARIADNE partner CSIC-Incipit (Spain) and Charlotte Hug of Université de Paris 1 Panthéon-Sorbonne	15
Total	**424**

The number of participants (424) thus well surpassed the target of 250 and we assume that over 250 have been young researchers. The overview above does not include local training organised by project partners at their own institutions, except they involved participants from other countries and/or trainers of other partners. Examples of joint training are the data management workshops at ÖAW-OREA and ZRC-SAZU in January 2016. Examples of local training are data preparation and deposit training offered regularly by the ADS and DANS digital archives. As a special case of local training we highlight the Archaeological Information Modelling course developed by CSIC-Incipit. In the ARIADNE impact evaluation we do not include courses and lecturing of partners at universities (which are not part of the funded project work). The Santiago course is highlighted below as it could serve as a blueprint for nourishing conceptual modelling skills in archaeology curricula also at other universities in Europe.

CSIC-Incipit Archaeological Information Modelling course

Researchers of CSIC-Incipit, César Gonzalez-Perez and Patricia Martín-Rodilla, in collaboration with Charlotte Hug of Université Paris 1 Panthéon-Sorbonne, since 2011 have held a post-graduate course on Conceptual Modelling for Cultural Heritage at the University of Santiago de Compostela, Spain (and other universities). In 2013 they adapted it for a special course on Archaeological Information

[55] ARIADNE (2013-09-10): Ariadne's first training workshop, http://www.ariadne-infrastructure.eu/News/Ariadne-s-first-training-workshop and http://www.ariadne-infrastructure.eu/Events/ARIADNE-Workshop-EAA-2013

Modelling in the Master's Degree programme Archaeology and Sciences of Antiquity at the university[56], held annually since then.

The course for archaeologists is particularly innovative in that it addresses students early on in their academic career (master's level) and offers hands-on development of skills that are uncommon in other archaeology curricula. The result is that archaeologists often lack modelling skills when they complete their studies. Instead, conceptual modelling has been appropriated by software engineers who often lack domain knowledge in the humanities. The Santiago course on Archaeological Information Modelling could serve as a blueprint for nourishing conceptual modelling skills in archaeology curricula also at other universities in Europe and beyond (e.g. South America).

The course aims to enable students without background in information technology and software development acquiring operational skills in conceptual modelling in just 5 days, 30 hours of teaching and a mini-project developed by the students during the course. Typically 10 students participate in the course. As conceptual modelling language ConML[57] is being used, which has been designed with non-experts in information technologies in mind. ConML is oriented towards the creation of people-oriented rather than computer-oriented implementation models (in opposition to UML, for instance), and specifically addresses modelling needs that are rarely considered in natural sciences, e.g. subjectivity, temporality or vagueness. The course starts from essentials such as concepts of object, classes, attributes, associations, modelling patterns, modularity and others.

Development of new training programmes

ARIADNE TNA and other training offers have inspired related initiatives to plan or rework training efforts. For example the CIDOC-CRM community is planning a new framework of training for CIDOC-CRM application to cultural heritage data. This initiative is taking inspiration from the ARIADNE TNA program and the experience from the ontology mapping training at PIN VAST-Lab (as part of the TNA programme) and training provided by FORTH-ICS[58].

Current re-organisation of training offers is also motivated by available new tools. In the case of CIDOC-CRM training the Mapping Memory Manager - 3M developed by FORTH-ICS (see *Section 4.6.2*). More general training courses in information management for cultural resources will benefit from the interactive Vocabulary Mapping Tool for thesauri, taxonomies and other knowledge organisation systems offered by USW (see *Section 4.6.4*). Concerning tools and services for the generation and use of advanced 2D/3D content thee is a high demand for training of post-graduates in archaeology and cultural heritage in general (e.g. representation/reconstruction of 3D objects, buildings and landscapes). The interest for TNA and other training at conferences and workshops has been the highest in this areas and the web-based services for advanced 2D/3D content provided by CNR institutes (CNR-ISTI, CNR-ITABC) are being used by a growing number of researchers (see *Section 4.6.7*).

4.3.4 Summary of results

In the Trans-national Access (TNA) programme three ARIADNE competence centres (Athena RC, CNR-ISTI and PIN) offered access for group visits (summer school format) and individual visits of one week.

[56] Master's degree Archaeology and Sciences of Antiquity, http://www.usc.es/masteres/en/masters/arts-humanities/archaeology-sciences-antiquity; evaluation of the courses is reported in Gonzalez-Perez & Martín-Rodilla (2015).

[57] ConML, http://www.conml.org ; ConML has also been used to design the CHARM - Cultural Heritage Abstract Reference Model (http://www.charminfo.org) that is described in *Section 4.6.3*.

[58] For example, the CIDOC-CRM Mapping Workshop for Humanities Scholars and Cultural Heritage Professionals at Oxford e-Research Centre, UK, 9-10 Nov. 2015.

The study visits were offered in the years 2014, 2015 and 2016, with a TNA travel bursary for eligible participants. The TNA programme centred on data-related skills as required for archaeological projects, e.g. data management planning, dataset development, 2D/3D documentation, data mapping and ontologies. The number of applications (136) was below the envisaged 300, a target which on hindsight appears as unrealistic.

Over 100 researchers from European and other countries participated in the TNA programme, 97 with a TNA travel bursary. Of the researchers with TNA funding (97 bursaries) over 70% were young researchers (i.e. postgraduate students and postdoctoral researchers); 50% were female. The participants came from institutions in 23 countries (21 EU member states plus Serbia and Argentina); thirty different nationalities were represented, 20 EU member states plus Argentina, Australia, Brazil, Canada, China, Iceland, Norway, Serbia, Turkey and USA.

The feedback of the researchers on their achievements during the TNA summer schools and individual study visits for their projects was very positive. Also the organisation, logistics and trainers of the TNA offer were appreciated very much. The main potential improvement mentioned by several participants was the wish for longer training courses (more than one week).

In addition to the TNA programme, 424 researchers and practitioners benefited for their research and other tasks (e.g. data management) from 18 tutorials, workshops and short courses at events and partner sites. The number of participants well surpassed the target of 250. The training offer covered topics similar to the TNA and also had a strong focus on novel models, methods and tools offered by project partners. Some workshops also introduced participants to the TNA and data resources accessible online at ARIADNE partners.

ARIADNE TNA and other training offers have inspired related initiatives to plan or rework training efforts. For example, the CIDOC-CRM community is planning a new framework of training for CRM application to cultural heritage data. The current re-organisation of training offers is also motivated by available new tools and services developed by ARIADNE partners. Examples are the tools for knowledge organisation systems (Mapping Memory Manager for CIDOC-CRM/ontology; Vocabulary Mapping Tool for thesauri, taxonomies and other vocabularies) and advanced 2D/3D content tools and web-based services offered by CNR institutes (Visual Media and Landscape Services).

4.4 Online transnational access services

4.4.1 Brief description

The Integrated Infrastructures Initiatives (I3) model for Integrating Activities requires that such projects offer researchers access to physical research infrastructures (facilities/centres) and/or online services such as access to data or instruments. Therefore ARIADNE's transnational access (TNA) offer included online access to data resources and services available from (initially) three project partners. The offer has been expanded in the later phase of the project by searching across resources of the initial three and other partners through the ARIADNE data portal.

Impact indicators defined in the DoW:

- 800 different anonymous users availing of on-line infrastructure services during last year.
- 300 registered users of the on-line infrastructure services, the majority young researchers.

More specific and/or additional indicators: The indicators above have been defined before the project work when the setup of the e-infrastructure services was not fully clear. During the project it was decided that users will not have to register in order to use the ARIADNE data portal services. Therefore the second indicator is not relevant for the impact evaluation. Figures for the first indicator

will of course be provided (and are massively above 800). The sections that follow describe the access to the initial three online services, the expansion of the offer with addition resources (some newly developed in the project), and figures of access to the services of the ARIADNE data portal.

4.4.2 TNA online services

The initial set of ARIADNE online services, offered in the framework of the transnational online access (TNA) programme, comprised of services individually provided by three partners: Archaeology Data Service (ADS), ARACHNE iDAI.objects (DAI) and Fasti Online (AIAC). Below we give brief information about these services and effects of ARIADNE on their use.

Archaeology Data Service (ADS)

The Archaeology Data Service (ADS, http://archaeologydataservice.ac.uk) allows searching an online catalogue indexing over 1.5 million metadata records, including ADS collections and metadata harvested from UK historic environment inventories (Archsearch service). ADS holds over 40,000 unpublished fieldwork reports and over 1000 project archives, consisting of reports, images, data sheets and a variety of other primary resources. The ADS makes all of its holdings freely available for download or online research.

ARACHNE / iDAI.objects (DAI)

ARACHNE (http://arachne.dainst.org) is the central object database of the German Archaeological Institute (DAI) and the Archaeological Institute of the University of Cologne. The database contains over 1.8 million images of individual objects, buildings, monuments, topographies, scenes, inscriptions, reproductions; furthermore about 960,000 scanned pages of 4765 books are included.

Fasti Online (AIAC)

The Fasti Online service (http://www.fastionline.org) of the International Association of Classical Archaeology (AIAC) provides access to about 12,000 site summaries and reports of excavations across the Mediterranean and other countries since 2000; the database holds information about 3300 sites in 14 countries.

ARIADNE effects on individual services

From project start to March 2016, before the official launch of the ARIADNE portal, ARIADNE effects on the number of visitors or page views of the three services were mainly perceived around major conferences. While the service usage slightly increased during the period effects of ARIADNE could only be discerned when the project was present with sessions, workshops and other activities at major domain events (i.e. EAA, CAA, CHNT and others). Thereafter some access to data records via the data portal has been perceived by the three initial and other data providers.

4.4.3 ARIADNE portal

ARIADNE developed a data registry and portal which allow registering and making cross-searchable records of the three resources described above and several resources of other ARIADNE partners. The ARIADNE data portal[59] has been publicly launched on the 30th of March 2016 at the CAA conference in Oslo. The portal offers various services for cross-searching data records, i.e. based on subjects, period (date range) and location (map-based).

[59] ARIADNE data portal, http://portal.ariadne-infrastructure.eu

This section describes the data resources that are currently cross-searchable in the ARIADNE portal, highlights some examples of significant advances of project partners in making data accessible, and gives an outlook on data resources that may flow into the registry/portal in the future. Portal access figures are presented in the next section.

Resources in the ARIADNE portal

The following table gives brief information about the data resources that are currently cross-searchable in the ARIADNE portal. It includes information about the kind, volume and other details of each resource.

Partner	***Brief description of the resources in the ARIADNE portal***
ADS	*Archaeology Data Service* (see description in the section above): Over 1.5 million records, mainly sites and monuments records, but also 663 records of fieldwork archives (excavations, field surveys).
AIAC	*Fasti Online* (see description in the section above): 6310 records of excavation projects in several European countries.
ArheoVest	*Database of field surveys*: Documentation of archaeological surveys carried out in the Timiș County since 2006; 800 records, including over 500 newly discovered points of archaeological interest); currently 104 records in ARIADNE.
ARUP-CAS	*Digital Archive of Aerial Photographs*: Database of aerial images of sites and monuments collected since 2000 (about 10,000 items); is now part of the information system of Archaeological Map of the Czech Republic system (Kuna *et al*. 2015); 1207 records in ARIADNE.
CSIC-Incipit	*Sites of North-West Spain:* Archaeological sites documented by CSIC-Incipit during fieldwork in the 1990s and 2000s; 1 record of a subset of the Sistema de Información Arqueológica - SIA+ (which documents 5248 sites in Galicia, neigh-bouring and other areas).
Cyl-STARC	*STARC repository*: Records of 17 collections of STARC projects on artefacts, monuments and sites of Cyprus, mostly under the Department of Antiquities of Cyprus (some content also of fieldwork in Israel and Italy)[60]. The collections contain images (>2000), 3D objects (>300 3D-PDFs) and other documentation, including scans of historical literature (Vassallo *et al*. 2013; Vassallo & Hermon 2015).
DAI	*ARACHNE / iDAI.objects* (see description in previous section), 25,514 records included in ARIADNE, specifically of archaeological sites and monuments (24,195) and artefacts (1319), i.e. fortifications, residential buildings, temples, sarcophagi, grave goods, etc.
DANS	*E-depot for Dutch archaeology (EDNA)*: EDNA[61] contains over 21,000 archaeological reports and about 4000 data sets of surveys and excavations consisting of GIS data, data tables, photographs, drawings (in total over 1.5 million files). About 80% of the archaeological data are publicly accessible. 25,649 EDNA records included in ARIADNE, 19,868 concern archaeological interventions and 5782 other fieldwork archives.

[60] STARC Repository, http://public.cyi.ac.cy/starcRepo/

[61] E-depot for Dutch archaeology (part of the DANS' EASY system), http://www.edna.nl

DANS-DCCD	*Digital Collaboratory for Cultural Dendrochronology*: The DCCD[62] has been developed by KNAW-DANS and national partners since 2006, 2010-2013 with other European partners, and since 2013 further work has been conducted within ARIADNE (Jansma 2013). The DCCD contains measurement series of 5200 objects dating between 6000 BC and present; ca. 50% of the collection is derived from archaeological sites and structures, including maritime archaeological sites. Data sets are described according to the international TRiDaS standard. 4635 DCCD records are included in ARIADNE.
Discovery	*Archaeological Survey of Ireland*: 140,859 records of the National Monuments Service[63] (under the Department of Arts, Heritage and the Gaeltacht, Ireland) included in ARIADNE; the records contain the locations of surveyed sites and monuments.
	3D-ICONS Ireland: Record of the collection of 3D and other documentation of over 130 monuments, buildings and artefacts from Ireland, 252 are 3D representations, created by Discovery in the EU project 3D-ICONS (2012-2015) [64].
	Discovery Programme image collection: Record of the collection of over 1500 images from projects such as the Western Stone Fort Project, The Medieval Rural Settlement Project, The Lake Settlement Project and others[65].
	Leo Swan Aerial Photography: Record of the collection of over 6000 photographs of archaeological sites taken between the 1970s and the 1990s[66].
	Hanson/Oltean Archaeological Aerial Archive of Romania: Record of the collection of 160 images of archaeological aerial reconnaissance of the development of the landscape of Western Transylvania[67].
INRAP	*DOLIA - Documentation de L'Inrap*: DOLIA since 2009 is the catalogue of the scientific documentation created by Inrap units (based on the UNIMARC standard)[68]. The records provide a summary of the archaeological investigation and chrono-logical, geographical and subject information. The largest part of the currently about 32,000 records concern archaeological reports (ca. 27,000; each year Inrap produces about 2000 evaluation and excavation reports); other documentation such as plans, images and articles is being progressively added. 28,332 records included in ARIADNE.
MiBAC-ICCU	*CulturaItalia - Archaeological objects*[69]: ICCU serves as national aggregator of cultural information from the Italian Regions and other entities (in total 2.7 million records, including archaeological objects (>52,000 records). 38,524 CulturaItalia records included in ARIADNE (i.e. 1568 of the Soprintendenza Speciale per il Colosseo e l'archeologia di Roma).

[62] Digital Collaboratory for Cultural Dendrochronology - DCCD (DANS), http://dendro.dans.knaw.nl; project website: http://vkc.library.uu.nl/vkc/dendrochronology/Pages

[63] Archaeological Survey of Ireland (National Monuments Service), http://www.archaeology.ie

[64] 3D-ICONS (Discovery), http://www.3dicons.ie

[65] Discovery Programme image collection, stored on https://www.locloudhosting.net

[66] Leo Swan Aerial Photography (Discovery), https://lswanaerial.locloudhosting.net

[67] Hanson/Oltean Archaeological Aerial Archive of Romania (Discovery) https://hansonaerialphotography.locloud.pl

[68] DOLIA - Documentation de L'Inrap (Inrap), http://multimedia.inrap.fr/Dolia/p-17038-Accueil.htm

[69] CulturaItalia (MiBAC-ICCU), http://www.culturaitalia.it

MNM	*Hungarian National Museum - Archaeology Database*[70]: Records of archaeological interventions (58,106), fieldwork archives (11), sites and monuments (1043), burial databases (342), artefacts (200) and scientific datasets (169); metadata in Hungarian and English. The archive has been developed in ARIADNE. Initially intended for several hundred records, strong promotion by the museum allowed acquisition of nearly 60,000 contributed by archaeologists across Hungary; 59,871 records included in ARIADNE.
NIAM-BAS	*Archaeological Map of Bulgaria*: Database of several thousand sites and monuments (AIS-AKB) developed by NIAM-BAS; currently accessible only for authorised users[71]. Currently a subset of 468 records is included in ARIADNE.
ÖAW-OREA	*UK Material Pool*: Database of Urnfield Culture (Late Bronze Age, 13th-8th c. BC) sites in Austria[72], 569 site records included in ARIADNE.
	Franzhausen Kokoron: Record of the burial database of the late Bronze Age cemetery located in Franzhausen-Kokoron (Austria)[73]. The database contains information about the cremation graves, features (e.g. grave pits, position of urns) and finds (e.g. pottery, bronze objects) as well as results from analysis of human and animal remains; the 3827 data sets consist of text (in German) and images (Lochner & Hellerschmid 2010).
	UK Thunau: Record of the collection of scanned find drawings, photographs and other information from excavations of the Late Bronze Age and Medieval settlement in Thunau am Kamp, Lower Austria.
	dFMRÖ - Digitale Fundmünzen der Römischen Zeit in Österreich: Record of the database of Celtic, Roman and post-Roman period coin finds in Austria (including some in Romania). Database of the ÖAW Numismatic Research Group (75,565 accessible entries)[74], connected to FMRÖ series of publications since 1971.
SND	*Swedish National Data Service (SND) - Archaeological data*: SND archives archaeological data since 2011, so far mainly GIS data sets from fieldwork, incl. reports, shape files, and access databases[75]. Furthermore SND hosts the Swedish Rock Art Research Archive and some thematic databases (e.g. medieval churches in Scania). 463 fieldwork archives included in ARIADNE
ZRC-SAZU	*ARKAS - Archaeological Sites and Monuments Records of Slovenia*: ARKAS[76] provides information about site/monuments locations, information sources, level of research work and protection, and selected documentation of the Institute of Archaeology; 7634 records in ARIADNE.

[70] Hungarian National Museum - Archaeology Database, http://archeodatabase.hnm.hu/en

[71] NIAM-BAS: Automated Information System "Archaeological Map of Bulgaria" (AIS AKB), http://www.naim-bas.com/akb/

[72] UK_Material-POOL (ÖAW-OREA), http://www.oeaw.ac.at/praehist/projekte/bronzezeit/ukpool/index.html

[73] Franzhausen Kokoron database (ÖAW-OREA), http://epub.oeaw.ac.at/franzhausen-kokoron2/

[74] dFMRÖ - Digitale Fundmünzen der Römischen Zeit in Österreich (ÖAW Numismatic Research Group), http://www.oeaw.ac.at/antike/index.php?id=358

[75] Archaeological GIS material (SND), http://snd.gu.se/en/search-and-order-data/gis-data

[76] ARKAS – Arheološki kataster Slovenije (ZRC-SAZU), http://arkas.zrc-sazu.si

	ZBIVA - Archaeological Database of Early Medieval sites in the South-Eastern Alps: The ZBIVA database[77] provides information about sites, graves and objects found in the region, including links to literature and images concerning each site; 3002 records in ARIADNE.

Summary and outlook

In total 1,905,922 records from data resources of different types and sizes are integrated in the ARIADNE registry and portal. Currently the publishers of all resources are ARIADNE partners, with contributions by other institutions (e.g. the Archaeological Survey of Ireland of the National Monuments Service). Some additional resources of partners, affiliated institutions and projects are being considered for incorporation in the future.

At present the largest share of almost 1.7 million records come from sites and monuments inventories/databases (with the largest contribution so far from the UK via ADS). In the other categories of archaeological interventions (142,743 records), fieldwork archives (6924 records), burial databases (343), artefact databases or image collections (52,732 records) and scientific datasets (4835 records) other partners individually or together have larger shares than ADS. The largest part of records of scientific datasets currently comes from the Digital Collaboratory for Cultural Dendrochronology (4635 records).

Very important to note is the difference between collection/database-level and item-level records. Some resources typically can output all item records (i.e. artefact/image databases), for example iDAI.objects. This is also the case with sites & monuments databases where the items actually are the records of inventoried sites/monuments. Other resources provide records of sets of different data items, i.e. fieldwork archives, where the items such as reports, maps, images, drawings, etc. belong together. Still others are single records which indicate, describe and link to a web-accessible collection. Examples are records of project collections in the Cyprus Institute STARC repository or collections curated by the Discovery Programme. Typically these contain content such as 3D models, scanned documents, aerial photography and other images.

Examples of significant advances

There are examples which represent significant advances of partners with regard to the accessibility of archaeological data enabled by ARIADNE. Some resources have not been accessible before or only for a few authorised users, for example records of ArheoVest field surveys in the Romanian part of the Banat region or sites & monuments of NIAM-BAS' Archaeological Map of Bulgaria (AIS-AKB) system. The currently few records represent a first step towards providing many more, particularly from the AIS-AKB.

Other partners could considerably improve or implement new systems. The ZRC-SAZU Institute of Archaeology transferred the content of the ZBIVA database of Early Medieval sites in the South-Eastern Alps to the ARCHES platform (Getty Conservation Institute & World Monuments Fund)[78]. Thereby a legacy database (online since 2000), which could provide effective access to only parts of the content (sites and bibliography) became a full-blown GIS based web service, including all available content. The database information is available in Slovenian, English and German (except free text descriptions not in German), under the Creative Commons BY-NC-SA license. The about 3000 records are included in the ARIADNE registry/portal.

[77] ZBIVA Archaeological database of Early Medieval sites in the South-Eastern Alps (ZRC-SAZU), http://zbiva.zrc-sazu.si

[78] ARCHES, http://archesproject.org

The Hungarian National Museum implemented the Archaeology Database, a whole new system initially intended for several hundred own records. Strong promotion by MNM allowed acquisition of nearly 60,000 records (over 891,000 files) contributed by archaeologists across Hungary. The records cover archaeological interventions (>58,000), sites and monuments (>1000), and other research content (burial databases, scientific datasets, artefacts), with metadata in Hungarian and English. The records are included in the ARIADNE registry/portal.

Outlook

Some ARIADNE partners and associates consider providing further data. For example, INRAP sees as a possible next step to add over 4000 images from archaeological research of their Images d'archéologie/Iconothèque database[79] (Salas Rossenbach 2016). Additional future resources would also be much advanced data based on mappings of databases to CIDOC-CRM and recent special extensions of this ontology (see *Section 4.6.2*). For example the associated ARIADNE partner Soprintendenza Speciale per il Colosseo, Il Museo Nazionale Romano e l'Area Archeologica di Roma together with other subjects and technical experts (MiBAC-ICCU; University of Verona, Dept. Computer Science) has mapped the database of SITAR, the Archaeological Territorial Informative System of Rome[80] to CIDOC-CRM, including the CRMarchaeo extension. Several associated partners (cooperation agreements) and ongoing projects aspire to possibly provide data at this advanced level or at least records of various datasets.

Some examples can illustrate the range of records that may flow into the ARIADNE registry and portal: National Research Centre on Human Evolution (CENIEH, Spain) – reports of excavations and scientific analyses of prehistoric finds; University of Oxford, Research Laboratory for Archaeology and the History of Art (RLAHA) – metallurgical data of the Flow of Ancient Metal Across Eurasia (FLAME) database; Université de Tours, Laboratoire Archéologie et Territoires, CNRS – Archives du Sol (Soil Archives) Database; Andalusian Institute of Historical Heritage – archaeological datasets from the regional cultural heritage information system; Aarhus University, School of Culture and Society – database of metal-detector finds (DIME project), also Vrije Universiteit Brussel, Dept. Art and Archaeology – database of metal-detector finds (MEDEA project). Each of these institutions and projects (and others) has sent researchers to participate in ARIADNE TNA trainings, see *Section 4.1.2*. That section also includes information on the initiative of several institutions to develop national metal-detector finds databases and to use the ARIADNE platform (registry/portal) for data dissemination and visualisation. Furthermore addressed is the North African Heritage Archive Network (NAHAN) initiative which may need some years to prepare and make available a larger number of records.

4.4.4 Portal access figures

The impact indicators/targets for the ARIADNE portal ("on-line infrastructure services") defined in the project's Description of Work are: 300 registered users, the majority young researchers, and 800 different anonymous users during the last project year. The indicators/targets have been defined before the project work when the setup of the e-infrastructure services was not fully clear. During the project it was decided that users will not have to register in order to use the ARIADNE data portal services (therefore the first indicator is not relevant for the impact evaluation).

The second target is relevant and has been massively surpassed by the number of portal visitors. The available figures for the period January 2016 to begin of January 2017 are as follows:

- 10,819 visitors (the target was 800 users in the last project year),

[79] INRAP: Images d'archéologie/Iconothèque, http://www.images-archeologie.fr

[80] SITAR - Sistema Informativo Territoriale Archeologico di Roma, http://www.archeositarproject.it

- 15,400 sessions (average duration 3.31 minutes),
- 68,982 page views (on average 4.48 pages viewed/session).

In addition we note that there has been a significant increase in user activity on the ARIADNE portal from July 2016 onwards. The site demographics suggest that there is a worldwide audience for the ARIADNE portal. During the period, the UK has provided the main source of visitors (50%), followed by France (7.3%), Italy (5.86%), the United States (4.13%), Greece (4.08%), Ireland (3.34%), Germany (3.1%), the Netherlands (2.5%), Russia (2.49%) and Sweden (1.82%). Further statistics and details are given in ARIADNE (2017a/D4.7).

4.4.5 Additional web-based services

The ARIADNE portal services allow cross-searching data records (i.e. based on subjects, period/date range and location/map-based) and accessing discovered data in the repositories/databases of the providers. In addition, the portal includes a section that documents and links to different services and tools provided by project partners[81]. This section briefly describes the web-based services but not available software tools interested users must download and install; examples are the data conversion tool STELETO (USW) for tabular data and the software of the DCCD dendrochronological data repository (DANS).

In the ARIADNE impact evaluation mainly the web-based services for digital visual media and landscapes (terrains) are considered, which are provided by CNR laboratories. These services have been adapted and further developed for ARIADNE, responding to a strong demand for such services expressed by archaeological researchers in user needs workshops and trainings (ARIADNE 2017d).

Evaluation of their impact was not mandatory as no indicators/targets for such services were included in the ARIADNE's Description of Work defined in 2012. The other web-based services have not been developed in ARIADNE. However the Vocabulary Matching Tool, developed by USW in a project running in parallel to ARIADNE, greatly helped to accomplish the goal of using semantic annotation for data interoperability.

ARIADNE Visual Media Service

The ARIADNE Visual Media Service[82] (provided by CNR-ISTI) enables easy publication and presentation on the Web of three types of visual media: high-resolution images, Reflection Transformation Images (RTI, i.e. dynamically re-lightable images), and high-resolution 3D models. It is an automatic service that allows uploading media files on a dedicated server and to transform them into a web format for easy access and efficient remote visualization on the Web. The initial idea was to provide such a service for ARIADNE archives which contain RTI or 3D media assets. The service has been used in ARIADNE training events and is already being used by many researchers of other projects (see *Section 4.6.7*)

ARIADNE Landscape Services

The Landscape Services[83] for ARIADNE (provided by CNR-ITABC) are a set of online services that include large terrain dataset generation, 3D landscape composing and 3D model processing. The services employ powerful open source frameworks and toolkits. The main components are a cloud service, the terrain generation service, a terrain gallery, and the front-end web component for

[81] ARIADNE Portal: Services, http://portal.ariadne-infrastructure.eu/services

[82] http://visual.ariadne-infrastructure.eu

[83] http://landscape.ariadne-infrastructure.eu

interactive visualization. The services have been used in ARIADNE training events and are already being used by researchers of other projects (see *Section 4.6.7*).

Vocabulary Matching Tool

The Vocabulary Matching Tool[84] (provided by USW) allows users to align Linked Data vocabulary terms with Getty Art & Architecture Thesaurus (AAT) concepts. It is a web-browser based tool that eases the mapping between different vocabularies. The tool has been developed by USW in the UK AHRC funded SENESCHAL project (2013-2014) and utilized in ARIADNE for mappings between vocabularies of partners and the AAT in order to enable cross-searching of records (see *Section 4.6.4*). Other data interoperability initiatives where providers use different vocabularies can benefit from using this freely available service.

Vocabularies

The services section of the ARIADNE portal includes also online vocabulary services that can be used for terminology lookup. The vocabularies are in Linked Data format (SKOS) which means concepts/terms can be re-used for aligning and linking vocabulary and data resources. The vocabulary services are

- *Heritage Data vocabularies:* major British heritage thesauri from the SENESCHAL project[85],
- *iDAI.gazetteer:* the gazetteer of the German Archaeological Institute (DAI)[86],
- *iDAI.vocab:* several thesauri of archaeological terminology in different languages[87],
- *Thesaurus RA (Reperti Archeologici):* the thesaurus of the Italian Central Institute for Catalogue and Documentation (ICCD) for objects coming from archaeological excavations, curated by MiBAC-ICCU and PIN VastLab[88].

The important role of vocabularies in ARIADNE is addressed in *Section 4.6.4*.

4.4.6 Summary of results

Online transnational access services (ADS, Arachne, Fasti Online)

The initial set of ARIADNE online services, offered in the framework of the TNA programme, were three data services individually provided by Archaeology Data Service (ADS), ARACHNE/iDAI.objects (DAI) and Fasti Online (AIAC). From project start to March 2016, before the official launch of the ARIADNE portal, ARIADNE effects on the number of visitors or page views of the three services were mainly perceived around major conferences. While the service usage slightly increased during the period effects of ARIADNE could only be discerned when the project was present with sessions, workshops and other activities at major domain events (i.e. EAA, CAA, CHNT and others).

ARIADNE data portal – making a difference to single data services

During the project resources of the three initial online TNA service providers and several other partners have been prepared for incorporation in the ARIADNE dataset registry and cross-resource

[84] http://heritagedata.org/vocabularyMatchingTool/

[85] http://www.heritagedata.org/blog/services

[86] http://gazetteer.dainst.org

[87] http://archwort.dainst.org/thesaurus/de/vocab

[88] http://vast-lab.org/thesaurus/ra/vocab

search on the data portal. At present there are 16 data providers/publishers (ARIADNE partners) from which in total 1,905,922 records have been integrated in the ARIADNE registry and portal.

These are data resources of different types and sizes. At present the largest share of almost 1.7 million records come from sites and monuments inventories/databases (with the largest contribution so far from the UK via ADS). In the other categories of archaeological interventions (142,743 records), fieldwork archives (6924 records), burial databases (343), artefact databases or image collections (52,732 records) and scientific datasets (4835 records) other partners individually or together have larger shares than ADS. The largest part of records of scientific datasets currently comes from the Digital Collaboratory for Cultural Dendrochronology (4635 records).

Through incorporation in the data portal the volume and coverage of some data categories previously only accessible at individual websites have been increased greatly. In particular this concerns records of archaeological interventions (i.e. site watching briefs and excavation reports).

There are examples which represent significant advances of partners with regard to the accessibility of archaeological data enabled by ARIADNE. To mention but one example, the Hungarian National Museum implemented the Archaeology Database, a whole new system initially intended for several hundred own records. Strong promotion by the museum allowed acquisition of nearly 60,000 records (over 891,000 files) contributed by archaeologists across Hungary. The records are included in the ARIADNE registry/portal.

Some additional resources of partners, affiliated institutions and projects are being considered for incorporation in the future, i.e. resources proposed by institutions in cooperation agreements. These would also include resources not yet present in the ARIADNE registry/portal, i.e. metal-detector finds databases, soil datasets or scientific data of ancient metallurgy.

Anticipated future resources would also be much advanced data based on mappings of databases to CIDOC-CRM and recent special extensions such as CRMarchaeo. Several associated partners and ongoing projects aspire to possibly provide data at this advanced level or at least item-level records of various datasets.

Portal access figures

The impact indicators/targets for the ARIADNE portal ("on-line infrastructure services") were: 300 registered users, the majority young researchers, and 800 different anonymous users during the last project year. During the project it was decided that users will not have to register in order to use the data portal. For the use of the data portal in the last project year the figures for the period January 2016 to begin of January 2017 are as follows:

- 10,819 visitors (the target was 800 users in the last project year),
- 15,400 sessions (average duration 3.31 minutes),
- 68,982 page views (on average 4.48 pages viewed/session).

From July 2016 onwards there has been a significant increase in user activity on the portal. The portal website demographics suggest that there is an international audience for the portal. About 90% of the visitors were from Europe, 10% from other countries (i.e. United States 4.13%, Russia 2.49%).

Additional web-based services

A section of the portal presents and links to services and tools that are provided by ARIADNE partners. The section includes web-based services as well as available software tools users can download and install (i.e. the software of the DCCD dendrochronological data repository). The web-based services are the ARIADNE Visual Media and Landscape Services (provided by CNR laboratories), the Vocabulary Matching Tool (USW), and four vocabulary services that can be used for terminology

lookup and aligning and linking vocabulary and data resources (UK Heritage Data Vocabularies, Thesaurus RA - Reperti Archeologici, iDAI.gazetteer and iDAI.vocab).

4.5 Data interoperability and unified access

4.5.1 Brief description

The archaeological research community has been an early adopter of various digital methods and tools for data acquisition, organisation, analysis and presentation of research results of individual projects. Lagging behind other research fields, e.g. the natural and life sciences, is the provision of e-infrastructure and services for data sharing, discovery, access and (re-)use. The consequence is a high fragmentation of archaeological data and limited capability for collaborative research across institutional and national as well as disciplinary boundaries.

This unfavourable situation has been addressed by ARIADNE. ARIADNE developed a data infrastructure and services that allow cross-archive search, visualisation, access and (re-)use of data from providers located in different countries. The development centred on enabling interoperability of a large amount of data from project partners and other contributors, and providing unified access to the digital resources. Furthermore long-term preservation of data records has been implemented.

ARIADNE has enabled archaeological and other heritage institutions to describe their digital resources (datasets, databases, etc.) and associated services in a central registry[89]. The description of the resources and services follows a common model, the ARIADNE Catalog Data Model – ACDM, which is based on a W3C recommendation for dataset catalogues. ACDM compliant records are ingested and integrated in the metadata repository of the data registry[90]. In addition to the ACDM other controlled vocabularies such as subject thesauri and timespans of cultural periods are being used for integrating information. The ARIADNE data portal draws on this information to provide various services. The creation of the ARIADNE e-infrastructure, data registry and portal is a great achievement for the archaeological domain as it provides a common platform where dispersed data resources can be uniformly described, discovered, visualized and accessed.

4.5.2 Critical mass of data

The ARIADNE registry and portal have been set up to allow aggregation and cross-searching of data records from institutions and projects in Europe and beyond. Regarding the volume, coverage and type of records the following indicators/targets have been defined:

Indicators defined in the DoW	***Results***
○ At least 5,000,000 archaeological records available for access, covering at least 70% of European countries	
Number of archaeological records: a least 5,000,000	Not achieved: 1,905,922 records (see below)
Coverage of European countries: at least 70%	Not achieved: Lack of some large countries and low density in others (see below)

[89] ARIADNE Registry, http://registry.ariadne-infrastructure.eu

[90] The MoRe (Metadata & Object Repository) aggregator is employed for this task, http://more.dcu.gr; in the case of a small collection also provision of the metadata in an Excel file is possible.

○ 100,000 reports available for searching and browsing	Achieved: >150,000; records of archaeological intervention reports (142,743) and others
○ Rich information provided in terms of metadata and content, i.e. not only text records but endowed with images, 3D etc.	
Rich information in terms of metadata	Achieved: The records have been uniformly described based on the ARIADNE Catalog Data Model (ACDM)
Rich information in terms of content – non-textual data	Achieved: Several resources contain images and 3D models (e.g. Arachne, STARC Repository, 3D-ICONS Ireland and others)

Evaluation of results

***At least 5,000,000 archaeological records**:* The target of "at least 5,000,000 archaeological records available for access" obviously has not been reached; the current number of 1,905,922 records is 38% of the target.

A better result is achievable if more current and future information publishers can move from provision of collection-level to item-level records (on the difference see *Section 4.4.3*). However, to reach over 5,000,000 more large datasets need to be mobilised, particularly national sites and monuments databases and records of archaeological interventions (i.e. watching briefs, excavation reports, building surveys). These resources are often under the control of national and regional authorities. The resources cannot be mobilised easily because of existing regulations, fear to expose archaeological site locations (i.e. potential looting), and need to digitise older reports which contain valuable information.

***Covering at least 70% of European countries**:* Due to the issue mentioned also this target has not been achieved. Some countries present a good coverage, i.e. Czech Republic, France, Ireland, Italy, Netherlands, Slovenia and UK, others a low density of coverage and some countries are missing. Among the missing countries is Germany. To cover Germany well mobilisation of records from the authorities of 16 German federal states (Bundesländer) would be necessary. Spain with 17 Autonomous Regions presents the same high challenge.

***Number of reports and richness of information**:* These targets have been achieved. With regard to the metadata especially the information on location, cultural periods (date ranges) and subjects merits to be highlighted.

4.5.3 Overcome fragmentation

ARIADNE addressed the issue that archaeological datasets often remain isolated, not interoperable and therefore not searchable in an integrated way. The ARIADNE Catalog Data Model (ACDM)[91] allows dataset providers to describe datasets in a central data registry based on a common data model. Datasets are often structured in a different way and circumscribed to different regions, periods or themes/subjects. Therefore additional methods such as geo-referencing of datasets and Linked Data methods (i.e. mapping of subject vocabularies) need to be applied to enable data interoperability and integrated service provision.

[91] ARIADNE Dataset Catalogue Model (ACDM) support website, http://support.ariadne-infrastructure.eu

Indicators defined in the Dow	*Results*
○ 100% of datasets integrated via mappings & crosswalks, or other appropriate integrating technologies such as GIS, Linked Data, etc., according to dataset typology	100% of datasets integrated based on the ACDM data model
○ 100% of all datasets with a spatial component integrated in a common GIS platform	Geo-referenced resources (71% of the total) integrated, OpenStreetMap for map-based browsing of information[92]
○ 25% of datasets linked as Linked Open Data (LOD)	100% of the ACDM based dataset metadata transformed and available as LOD (see below)
○ 30% increase in services provided (compared to currently available ones)	ARIADNE provides new and advanced services not provided by others in the sector (see below)

Evaluation of results

30% increase in services provided (compared to currently available ones):

ARIADNE provides new and highly advanced services not provided by others in the sector. The ARIADNE registry and portal are unique services newly developed and offered by the project. These services enable integrated, cross-archive search of data resources at the European level which were not available before. Other services developed or offered by partners through ARIADNE are also not available from others, at least not with the highly advanced capabilities provided. Examples are the ARIADNE Visual Media and Landscape Services and the Vocabulary Matching Tool. In summary, the availability of new and highly advanced services through ARIADNE has been increased, but a comparison and percentage of increase cannot be given.

25% of datasets linked as Linked Open Data (LOD):

Linked Open Data are openly accessible data resources that are based on W3C recommended standards, i.e. the basic Resource Description Framework (RDF) and the Simple Knowledge Organization System (SKOS) for vocabularies. The ARIADNE Catalog Data Model (ACDM) is based on the W3C Data Catalog Vocabulary (DCAT)[93] standard, adapted for the description of archaeological data resources. In addition to describing their resources following the ACDM, record providers also had to provide essential information of the metadata based on common standards. This requirement particularly concerns locations (origin), cultural periods (date ranges) and subjects of the described resources (see below). The target of 25% of datasets linked as LOD has been surpassed by transforming all ACDM based dataset metadata to Linked Data that is stored in an appropriate database (Virtuoso) and can be queried via a dedicated Linked Data server hosted by ARIADNE partner CNR-ISTI (ARIADNE 2017f).

Enabling integrated search

The ARIADNE data portal allows integrated searching across the various data resources. To enable such searching record providers had to provide essential information of the metadata based on common standards. This concerns the core search options “what” (subjects), “where” (location) and “when” (cultural chronology / date ranges).

[92] OpenStreetMap, https://www.openstreetmap.org

[93] W3C (World Wide Web Consortium) Recommendation (16 January 2014): DCAT - Data Catalog Vocabulary, http://www.w3.org/TR/vocab-dcat/

"What" (subjects)

Partners mapped terms from their thesauri or term lists to concepts of the Art & Architecture Thesaurus (AAT)[94] that is available in the Linked Data format SKOS. In total about 6000 terms (in different languages) have been mapped to the AAT. The mappings ranged from below 100 terms to extensive mappings required to cover large resources. For example, Inrap uses many terms of the PACTOLS thesaurus[95] for the subject metadata of their catalogue of archaeological reports (DOLIA). In total 1634 PACTOLS terms have been mapped to the AAT.

"Where" (location)

The dataset metadata should include standard lat./long. coordinates for locations to allow for map-based search of relevant resources on the data portal. As the common standard ARIADNE adopted WGS84 (World Geodetic System 1984)[96]. Most providers already had WGS84 based coordinates or could provide them where necessary. Important to note with regard to Linked Data is that the main Linked Data hub for geographic information is the GeoNames gazetteer[97], which also uses WGS84. The MoRe (Metadata & Object Repository) service of ARIADNE partner Athena-DCU can attach GeoNames URIs to geo-referenced geographic information in aggregated records.

"When" (cultural chronology / date ranges)

The data providers included in their metadata cultural period terms (e.g. "Iron Age") and date ranges (start/end dates) which apply to each term for their country/region. Thereby data resources can be searched based on period names or date ranges. ARIADNE partners also collected and provided the new cultural periods system PeriodO with a set of 659 periods (Paleolithic to Modern times) for 24 European countries[98]. More specifically, the set gives dates for archaeological periods for geographical areas that correspond to modern states or regions. This information defines the cultural period for a given area and allows dates expressed only in years to be placed within a period. PeriodO provides unique resource identifiers (URIs) for periods which allow clear and stable linking of data resources which concern the same period. A new service component has been included in the MoRe aggregator to attach PeriodO URIs to period information in records collected for ARIADNE. ARIADNE promotes the use of PeriodO to allow for wider interlinking of data based on chronologies in Linked Data initiatives.

4.5.4 Unified access

The indicators/targets for unified access concern the ways users of the ARIADNE portal can search and access data from different sources. The portal provides the common interface while specific interfaces allow for different modes of data search, visualisation and access according to the search paradigm and data searched.

Indicators defined in the DoW:

- 100% of datasets accessible through a common interface.
- 100% of datasets availing of innovative visualization and semantic annotation tools (where applicable according to dataset type).

[94] Getty Vocabularies as Linked Open Data, http://www.getty.edu/research/tools/vocabularies/lod/index.html

[95] PACTOLS Thesaurus (FRANTIQ, CNRS), http://pactols.frantiq.fr

[96] World Geodetic System 1984 (WGS 84), http://earth-info.nga.mil/GandG/wgs84/

[97] GeoNames, http://www.geonames.org

[98] ARIADNE set of cultural periods in the PeriodO system, http://n2t.net/ark:/99152/p0qhb66;

The first indicator is fulfilled by the ARIADNE portal which provides the common interface for all services and datasets. The portal allows different ways to search data, based on subjects, locations (map-based), and cultural period terms (e.g. "Bronze Age") and date ranges (start/end dates) which apply to particular countries/regions. The table below gives an overview of the different search options and basic and more advanced visualisation options.

The semantic annotation tools mentioned do not concern annotation of the data on the portal. The portal does not offer tools for end-users to annotate datasets, which data providers perceive as inappropriate or would require difficult to manage quality control. The tools concern semantic annotation of datasets by the providers; these are addressed in *Section 4.6.4*.

Detailed and/or additional indicators	***Results***
Search & browse and visualisation interfaces:	
○ Full-text search over the data records	Available
○ Tag cloud based search	Available, entry level (in English), but with multi-lingual results
○ Keyword/subjects-based search, including term suggestion	Available, multi-lingual
○ Thematically similar records	Accessed records include a list of thematically similar records, if available
○ Map-based search & browse	Available (based on OpenStreet-Map); the service includes indication of available records when zooming into the map
○ Geographically similar records	Accessed records include a list of geographically similar records, if available
○ Timespan-based search	In a visual interface that allows selecting timespans
Advanced object visualisation and manipulation: If content providers employ the services provided by the CNR laboratories	
○ *High-resolution 2D images / Reflectance Transformation Images (RTI):* Manipulation e.g. zooming in/out over the high-resolution images, panning, real-time relighting (for RTI data); supported in standard web pages and web browsers	Provided by CNR-ISTI
○ *3D objects:* Manipulation e.g. rotate using a virtual trackball, zooming in/out, pan; all actions are performed over a multi-resolution representation that enables web-based access to high-resolution models; supported in standard web pages and web browsers	Provided by CNR-ISTI
○ *3D terrain and landscape models:* Camera and field-of-view manipulation, e.g. rotate, pan and zoom over large multi-resolution terrain datasets in real-time using web browsers, including full support for desktop and mobile multi-touch devices. Scene-graph support allows basic transformation	Provided by CNR-ITABC

and manipulation of items on top of virtual 3D dataset. Advanced lighting models (e.g. physically-based rendering) can be employed to simulate reflective surfaces (rivers, lakes, etc.) and other environment effects for presentation purposes	

4.5.5 Long-term preservation of records

Indicator defined in the DoW: Long-term preservation process activated for all datasets.

More specific and/or additional indicators: The ARIADNE e-infrastructure does not provide a central data storage and preservation centre. Primary data are deposited and curated at data archives/ repositories of partners or other institutions. The long-term preservation services addressed in this section concern the data records (metadata) which are ingested, enriched and included in the ARIADNE data catalogue.

Long-term preservation and access for the dataset records (metadata) of the ARIADNE registry catalogue is implemented. The records are being ingested, enriched and provided to the data catalogue. Ingest and enrichment actions are automatically documented as PREMIS events[99] and stored with each data record. Multiple actions generate new PREMIS records that are stacked together and preserved, thus form a complete data curation log. The ARIADNE dataset catalogue is stored within the e-infrastructure for long-term access.

The ARIADNE catalogue has been transformed into a Linked Data graph using the CIDOC-CRM vocabulary and stored in a RDF database (triple store). The database provides an interface (SPARQL endpoint) so that the Linked Data can be utilized by services internal and external to the ARIADNE e-infrastructure. Currently it is mainly used for demonstrating CIDOC-CRM based data integration at the collection and item level.

It is worth noting that the transformation and storage of the ARIADNE catalogue in RDF and RDF Schema adds to the goal of long-term preservation and access; because the results are based on standard models and vocabularies which are more long-lived than ad-hoc solutions. In particular, the CIDOC-CRM is an ISO standard since 2006 (ISO21127:2006, renewed as ISO21127:2014) that is a more robust model than the ARIADNE Catalogue Data Model developed in the project. Furthermore, RDF and RDF Schema are W3C recommendations and as such de facto standards. This guarantees that the catalogue, stored e.g. as an RDF dump, will be accessible for a longer period than any corresponding dump in a non-standard format.

4.5.6 Summary of results

The summarization of the results of the activities reported in this chapter, including explanation of concepts and achievements, is included in the Summary Report, *Section 2.4.5*.

[99] PREMIS Data Dictionary for Preservation Metadata, http://www.loc.gov/standards/premis/

4.6 Progress in data documentation, linking, processing and visualisation

4.6.1 Brief description

This innovation dimension concerns novel methods that enable enhanced documentation, linking, processing and visualisation of archaeological data. Specifically, project partners developed and applied extensions of the CIDOC Conceptual Reference Model as required for archaeological documentation, and enabled semantic linking of data resources based on Linked Data methods. They explored data mining techniques to identify patterns in data resources, and applied natural language processing methods to extract information from "grey literature" such as archaeological fieldwork reports. Furthermore novel services for visual media (e.g. 3D models) were a major focus of technological development which produced innovative solutions for the ARIADNE community and other users. Across these focus areas of RTD several useful methods and tools have been produced as well as pilot applications that demonstrate new capabilities for digital archaeology.

Indicators defined in the DoW:

- Conceptual Reference Model extended to cover new domains as relevant to archaeological research (e.g. monuments and standing structures, excavation data and scientific laboratory analysis).
- Open Linked Data annotation and integration methods established and demonstrated for archaeological cases.
- Data mining techniques established and demonstrated.
- Natural language techniques established and demonstrated.

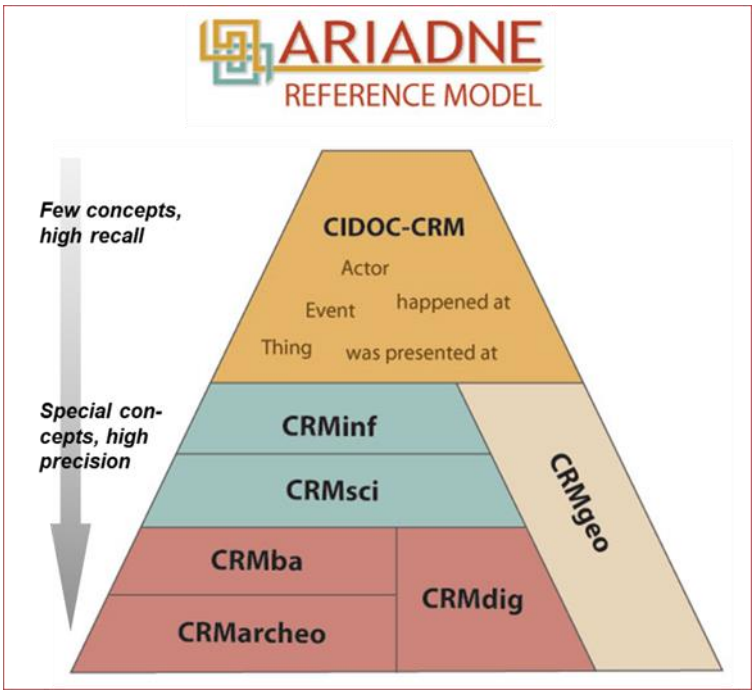
The work conducted and results achieved are described below; the demonstrators are presented in *Annex D*.

4.6.2 CIDOC-CRM extensions

The CIDOC Conceptual Reference Model (CIDOC-CRM)[100] has been developed by an interdisciplinary team of experts under the aegis of the International Committee for Documentation (CIDOC) of the International Council of Museums (ICOM). The CIDOC-CRM is a formal ontology intended to facilitate the integration, mediation and interchange of heterogeneous cultural heritage information. The ontology provides definitions and a formal structure for describing the concepts and relationships used in cultural heritage documentation. It offers a common and extensible semantic framework for information systems that can integrate different sources of cultural heritage information, such as that published by museums, libraries and archives. The ontology has been release in 2006 as an official standard of the International Organization for Standardization (ISO 21127:2006).

In ARIADNE several extensions to the CIDOC-CRM have been created or enhanced which together form the ARIADNE Reference Model (ARIADNE 2016d). This model is intended to allow the accurate documentation of complex entities and relations of archaeological/scientific observations and analysis, data integration and search, involving reasoning over the distributed data and knowledge.

[100] CIDOC - Conceptual Reference Model (CIDOC-CRM), http://www.cidoc-crm.org; see Definition of the CIDOC Conceptual Reference Model. Version 6.1, February 2015, http://www.cidoc-crm.org/docs/cidoc_crm_version_6.1.pdf



Special ARIADNE workshops organised by FORTH-ICS addressed modelling of archaeological excavation and scientific data[101]. For example, the workshop on modelling scientific data compared the protocols of different scientific methods that are employed in archaeological research (i.e. geophysical survey, elemental analysis of archaeological objects, TL/OSL ceramics analysis, dendrochronology, isotope analysis, DNA analysis).[102]

The objective was to identify which generic metadata schemata and their discipline-specific specialization could allow building reference data collections, information integration and re-evaluation of results based on new evidence. It became apparent that the processes of scientific investigations need to be modelled in greater detail, as extensions of the CIDOC-CRM, to enable e-infrastructures services support the research processes and adequate documentation.

Indicator defined in the DoW: Conceptual Reference Model extended to cover new domains as relevant to archaeological research (e.g. monuments and standing structures, excavation data and scientific laboratory analysis).

[101] ARIADNE workshops: Excavation data and relevant applications (Heraklion, Crete, 29-31/5/2013); Context, stratigraphic unit, excavated matter (Plakias, Crete, 19-22/8/2013); Modeling scientific data (Plakias, Crete, 21-24/7/2014).

[102] ARIADNE (2014-09-12): Modeling scientific data: workshop report, http://www.ariadne-infrastructure.eu/News/Modeling-scientific-data

Detailed and/or additional indicators	***Results*** [103]
○ CRMgeo: spatio-temporal model that articulates relations between the standards of the geospatial and the cultural heritage communities (integrates CRM with OGC standards; applications such as GeoSPARQL)	New extension, v1.0, April 2013
○ CRMdig: model of digitisation processes, to encode metadata about the steps and methods of production ("provenance") of digital representations such as 2D, 3D or animated models (validated in several projects)	Enhanced extension, v3.2, August 2014
○ CRMsci: model for integrating metadata about scientific observations, measurements and processed data (validated in archaeology, biodiversity and geology cases)	Enhanced extension, v1.2.2, August 2014
○ CRMinf: model for integrating data with scholarly argumentation and inference making in descriptive and empirical sciences (validated with scholarly annotations)	New extension reducing the argumentation model in Doerr *et al*. (2011) and harmonizing it with CRMsci, v0.7, February 2015
○ CRMarchaeo: model for integrating metadata about the archaeological excavation process, introduces concepts of stratigraphy and excavation (validated with archaeological records)	New extension, v1.4, April 2016
○ CRMba: model for investigating ancient/historic buildings, the relations between building components, functional spaces, topological relations and construction phases through time and space (Ronzino 2015; Ronzino *et al*. 2016); harmonized with CRMarchaeo	New extension, v1.4, April 2016
○ ARIADNE Reference Model: CIDOC-CRM + set of new or enhanced extensions	ARIADNE Reference Model, v1.0, April 2016

A further CIDOC-CRM extension has been suggested by PIN researchers for epigraphy, CRMepi (Felicetti, Murano *et al*. 2016). At the 2015 CIDOC-CRM SIG meeting in Crete (6 October 2015) it was proposed that CRMepi is regarded as a general model and the CIDOC-CRM class "E34 Inscription" be revised accordingly[104]. Therefore a new extension is being developed that applies to all text forms such as inscriptions in stones, cuneiform tablets, papyri and so on. The ongoing work on this extension, now CRMtex, has been presented at the CIDOC-CRM SIG in August 2016 and other occasions.

Mapping of databases to the CIDOC-CRM and extensions

The CIDOC-CRM has been extended to allow addressing better the complexity of archaeological data integration. The enhanced capability provided by the ARIADNE Reference Model has been confirmed in the mapping of a number of representative databases to relevant parts of the model as well as

[103] Description of the ARIADNE Reference Model and individual extensions (including reference document, presentation, RDFS encoding) is available at http://www.ariadne-infrastructure.eu/Resources/Ariadne-Reference-Model

[104] CIDOC-CRM SIG meeting, Heraklion, 6 Oct. 2015, http://www.cidoc-crm.org/special_interest_meetings.html

pilot applications (demonstrators). A new tool, the Mapping Memory Manager (3M)[105] has been developed by ARIADNE partner FORTH-ICS to facilitate the mapping process and the mapping validation. The mapping process is supported by the X3ML Mapping Framework that ensures the integrity and preservation of the "meaning" of the initial data (Minadakis *et al*. 2016). The mappings are briefly presented below, demonstrators which use such mappings in *Annex D/D2-D5*.

Database	***Results***
○ Mapping of the ACDM model of the ARIADNE dataset catalogue, carried out by FORTH-ICS, CNR and PIN	The ACDM model has been mapped to CIDOC-CRM and a set of integrated queries implemented in order to validate the adequacy of the models. This mapping is being used to support data integration both at the catalogue and at the item level; item-level integration has been demonstrated in application pilots (i.e. coins, sculptures and other demonstrators).
○ DAI: Revised CIDOC-CRM mapping of the Arachne database	The existing CIDOC-CRM mapping of Arachne was revised and refined, including an overhaul of Arachne's OAI-PMH interface to make these mappings available. Also the iDAI.Gazetteer of places and place names was mapped to CIDOC-CRM. Arachne records have been used in the coins and sculptures demonstrators.
○ DAI: Mapping of the Athenia Agora excavation database	The database of the Athenian Agora excavation (American School of Classical Studies in Athens) presents a case of highly contextualized research data. The most relevant parts of the freely accessible database were mapped to CIDOC-CRM, using the extensions CRMarchaeo and CRMsci. The mapping results have been used together with DAI and other datasets in the sculptures demonstrator.
○ DAI: iDAI.field database of the Pergamon project (mapping by DAI); iDAI.field is a relational database for documentation of archaeological field work; over 35 DAI projects worldwide use it with different methods (i.e. excavation, survey, object studies, architectural studies, and others)	The most used tables and attributes of iDAI.field were mapped to CIDOC-CRM, using the extensions CRMarchaeo and CRMsci. Documentation of coin finds has been employed together with other datasets in the coins demonstrator.
○ ÖAW: Gräberfeld Franzhausen Kokoron, a database of 403 cremation graves of the Late Bronze Age Urnfield Culture (1050-800 BC) in eastern Austria; the database documents features, finds and results from analysis of human and animal remains (mapping by FORTH-ICS and ÖAW-OREA)	The mapping of this database with about 3800 records served as a test case for the use of CRMarchaeo (excavations) and CRMsci for scientific observation/measurements (Doerr *et al*. 2016).

[105] Mapping Memory Manager (3M), http://www.ics.forth.gr/isl/3M

○ ÖAW: dFMRÖ, a relational database of pre-Roman and Roman Imperial period coins found in Austria and Romania, developed by the ÖAW Numismatics Research Group (mapping by FORTH-ICS and ÖAW-OREA).	The database schema of the dFMRÖ was mapped to CIDOC-CRM, using also the CRMdig extension and a specialized extension for coins covering the need to map categorical information (Doerr *et al*. 2016). The database provided a good example for mapping of a large class of well-defined traditional databases where there is a need to address and separate both categorical and factual information. Results have been employed together with other datasets in the coins demonstrator.
○ MiBAC-ICCU: Mapping of the schemas of the Central Institute for Catalogue and Documentation (ICCD) for archaeological finds (RA) and monuments and complexes (MA/CA), carried out with support by PIN (Felicetti *et al*. 2013; Felicetti, Galluccio *et al*. 2016).	Schema elements have been mapped to the CIDOC-CRM to evaluate the ability of the ARIADNE Reference Model to integrate complex entities and relations. The complex schemas have been modelled with classes and properties of the core CIDOC-CRM using, where required, more specialised classes and properties of the CRM extensions.
○ MiBAC-ICCU: Mapping of the database schema of SITAR, the Archaeological Territorial Informative System of Rome, carried out by MiBAC-ICCU in cooperation with domain experts of the Soprinten-denza Speciale per il Colosseo, il Museo Nazionale Romano e l'Area Archeologica di Roma, and the Department of Computer Science of the University of Verona.	The SITAR system manages different types of data sets including information about monuments, archaeological finds, survey and conservation work, archival documents, bibliographic references and others. A mapping between the SITAR database schema and the concepts of CIDOC-CRM and CRMarchaeo has been carried out and SITAR data extracted and transformed to RDF.

In the application pilots (demonstrators) some of the CRM mappings and selective mappings of other databases with the 3M tool have been used together with other vocabularies to demonstrate advanced capability to search data resources and identify relevant related information.

4.6.3 CHARM modelling

Research and practice in archaeology often generates, and needs to manage, a large amount of information that presents complex categorisation and relationships between objects and phenomena. Therefore archaeologists need skills and tools for conceptual modelling. The quality of the conceptual models that are employed when gathering, organising, processing and reporting archaeological information determines to a large extent the quality of the outcomes of the research work.

Project partner CSIC-Incipit since 2011 has developed ConML, a conceptual modelling language specifically for the humanities and social sciences[106], and the CHARM - Cultural Heritage Abstract Reference Model[107]. CHARM is designed to be used by researchers and practitioners in archaeology and heritage and extended to meet their particular needs (Gonzalez-Perez *et al*. 2012; Gonzalez-Perez & Martín-Rodilla 2014). CHARM is expressed in ConML which also facilitates the extension of the model into particular representations that best suit the particular needs of different projects.

[106] ConML, http://www.conml.org

[107] CHARM, http://www.charminfo.org

As an example, CHARM has been applied for the Iron Age settlement of Castrolandín (located in Galicia, North-West Spain) covering different documentation: initial cultural heritage documentation, historical and ethnographic documentation of a traditional celebration on the site between the late 19th and the mid-20th centuries, new archaeological investigations and some re-interpretation of previous results, and the decision of the regional government to apply protection schemes on both the site and the celebration. The example illustrates how different teams belonging to different communities (archaeologists, ethnographers, the regional government) that adopt CHARM, each working with a different particular model, can still generate a common object model and attain seamless interoperation for transdisciplinary work (Gonzalez-Perez *et al*. 2012).

Within ARIADNE CSIC-Incipit has made available a programming library that can be used with CHARM models, i.e. a modelling engine capable of storing and manipulating ConML models, and examples of such models. The library can be used by software developers who want to create systems for processing archaeological models that are based on CHARM. Models expressed in CHARM can be exported in SKOS or OWL formats and used in Linked Data environments.

4.6.4 Linked Data methods

ARIADNE employs Linked Data methods for integration of vocabularies and metadata within the project and preparing the ground for further linking of resources also beyond the ARIADNE pool of resources.

The project uses Linked Data methods in several ways that support the integration of datasets. Linked Data in W3C recommended formats (RDF, RDFS, SKOS and others) have been created through the mapping of subject terms from thesauri (or term lists) of data providers to concepts of the Art & Architecture Thesaurus (AAT) in RDF/SKOS format. Several datasets have been mapped to the CIDOC-CRM and extensions (which are expressed in RDFS) and used in pilot applications which demonstrate advanced data integration capability. ARIADNE partners have developed and made available open source tools that support such mappings (Vocabulary Matching Tool, Mapping Memory Manager). Partners also have supported the transformation of existing vocabularies to SKOS as well as the creation of new vocabularies in this Linked Data standard.

Indicator defined in the DoW: Open Linked Data annotation and integration methods established and demonstrated for archaeological cases.

More specific and/or additional indicators: In the sections below we give an overview of the Linked Data methods and tools that have been applied, enhanced or newly developed by ARIADNE researchers and developers. Use of vocabularies in Linked Data format for data mining and natural language processing is addressed in the next two sections. The ARIADNE pilot applications (demonstrators) employing Linked Data are described in *Annex D/D1-D6*.

Linked Data annotation/mapping and integration

The table below gives an overview of the tools developed by partners for the semantic annotation/ mapping and integration of vocabularies and data as well as the main examples of mapping and integration. The latter include the mapping of several thesauri (or term lists) of data providers to concepts of the Art & Architecture Thesaurus (AAT) in RDF/SKOS format and the mapping of several databases to the extended CIDOC-CRM (the CRM and extensions are expressed in RDFS).

Detailed and/or additional indicators	***Results***
○ *Interactive Vocabulary Matching Tool:* A lightweight browser based application that presents concepts from chosen source and target vocabularies side by side, exposing additional contextual evidence to allow the user to make a more informed choice when deciding on potential mappings. The tool is for vocabularies already expressed in RDF/SKOS and can work directly with the Linked Open Data – querying external SPARQL endpoints rather than storing any local copies of complete vocabularies. The set of mappings developed can be saved locally, reloaded and exported to a number of different output formats.	Tool developed and provided open source by USW; the software is available on GitHub[108]
○ *Spreadsheet based mapping:* A second mapping approach has been developed for source vocabularies that are smaller term lists and not yet expressed in RDF. Such term lists are often available or can be easily represented in a spreadsheet. A standard sheet with example mappings was designed to support domain experts in the mapping of terms to the target vocabulary. A CSV transformation produces the representation of the mappings in RDF/JSON format. The spreadsheet also contains a tab to record metadata for the mapping.	Tool developed and provided by USW, available on GitHub[109]
○ *Mapping of partner subject terms to a common semantic backbone:* Mappings of terms from partner thesauri (or term lists) to terms of the Art & Architecture Thesaurus (AAT) in SKOS format to enable subject-based cross-search of data resources; the tools mentioned above have been used for these mappings (Binding & Tudhope 2016).	Terms used for all data resources in the ARIADNE registry have been mapped. In total about 6000 terms (in different languages); mappings ranged from below 100 terms to over 1600
○ *Mapping Memory Manager (3M):* The tool facilitates the mapping of databases to the (extended) CIDOC-CRM and the validation of the mapping; mappings can be exported in CRM compliant RDF.	Tool developed and provided open source by FORTH-ICS; the software is available on GitHub[110]
○ *Mapping of databases to the extended CIDOC-CRM:* Several representative partner databases (DB schemas) have been mapped with the 3M tool (see below) to the extended CIDOC-CRM; also the ARIADNE dataset catalogue model (ACDM) has been mapped to the CIDOC-CRM.	The mappings are briefly described in *Section 4.6.2*; mapped datasets have been employed in demonstrators (see below)
○ *Applications that use ARIADNE Linked Data:* Some of the ARIADNE pilot applications demonstrate advanced data integration and search capabilities offered by Linked Data that is based on the extended CIDOC-CRM and different	The demonstrators on different subjects (coins, sculptures, wooden material and others) are documented in *Annex D/D1-D6.*

[108] Interactive Vocabulary Matching Tool, http://heritagedata.org/vocabularyMatchingTool/; source code for local download and installation available on GitHub, https://github.com/cbinding/VocabularyMatchingTool

[109] ARIADNE subject mappings: Spreadsheet template and conversion, https://github.com/cbinding/ARIADNE-subject-mappings

[110] Mapping Memory Manager (3M), http://www.ics.forth.gr/isl/3M; source code, https://github.com/isl/Mapping-Memory-Manager

vocabularies.	
○ *ARIADNE Linked Data storage and access:* The ARIADNE catalogue metadata has been transformed to Linked Data that is stored in an appropriate database and can be queried via a dedicated Linked Data server hosted by ARIADNE partner CNR-ISTI (ARIADNE 2017f).	Catalogue metadata stored in a Virtuoso[111] Linked Data store (also some vocabularies are included); the data can be provided as an RDF dump or queried via a SPARQL end-point.

Linked Data vocabularies in SKOS

Vocabularies such as thesauri and taxonomies represent essential knowledge structures and terminology of domains of knowledge. The domain of cultural heritage and archaeology has a particularly rich array of such resources. The move towards Linked Data makes it necessary to provide vocabularies in Linked Data formats (RDF, SKOS, OWL). ARIADNE is a project and therefore not in a position to publish and maintain vocabularies. This must be done by the institutional owners of the vocabularies.

But ARIADNE partners produced or helped others with tools and expertise to produce vocabularies in SKOS format. Such work has been carried out before, in parallel to, or within ARIADNE. There is an increasing collaboration on, and sharing of, such vocabularies, and ARIADNE has contributed to this development. The following table gives an overview of vocabulary development and/or sharing in the context of ARIADNE. Vocabularies indicated with /* are included in the services section of the ARIADNE portal[112].

Vocabulary /*	***Owner***	***Brief description***
Dendrochronology multi-lingual vocabulary[113]	DANS-DCCD	A vocabulary in SKOS format for documenting data resulting from dendrochronological analysis; produced by DANS with support by USW. The vocabulary is being employed for the DCCD - Digital Collaboratory for Cultural Dendrochronology and available also to other users.
Archeologisch Basisregister (ABR+)[114]	RCE	The Cultural Heritage Agency / Rijksdienst Cultureel Erfgoed (RCE) of the Netherlands have produced RDF/SKOS versions of their Archeologisch Basisregister (ABR+) and other thesauri. ARIADNE partner DANS uses ABR terms for metadata of archaeological datasets. ABR thesauri also have been used to explore the extraction of (meta-)data from Dutch fieldwork reports based on named entity recognition (ARIADNE 2017i).
iDAI.gazetteer[115]/*	DAI	The gazetteer is a web-based service connecting names of places and other geographical entities with coordinates. It was initially built as an authority file for any geo-related information in information systems of the DAI, and for linking with information that refers the same geographical entities but uses another gazetteer. For example, DAI uses it to provide data of the

[111] OpenLink Virtuoso, http://virtuoso.openlinksw.com

[112] ARIADNE Portal: Services, http://portal.ariadne-infrastructure.eu/services

[113] Tree Ring Data Standard (TRiDaS), vocabularies: http://www.tridas.org/vocabularies/

[114] Rijksdienst Cultureel Erfgoed: Erfgoedthesaurus, http://www.erfgoedthesaurus.nl

[115] iDAI.gazetteer, http://gazetteer.dainst.org

		iDAI.objects database to the Pelagios initiative, 87,735 references concerning 5363 places[116]. The gazetteer can be used as a terminology look-up service and the concepts/terms may be re-used for interlinking data records.
iDAI.vocab[117]/*	DAI	iDAI.vocab is a group of 14 thesauri of monolingual archaeological terminology aimed to collect and organise the terminology used in DAI services. The thesauri are in different languages (Arabic, Chinese, English, Farsi, French, German, Greek, Hungarian, Italian, Portuguese, Russian, Spanish, Turkish, Ukrainian) and of varied size (ranging from below 100 to several thousand terms). The German thesaurus serves as the central hub to and through which the other thesauri are linked. The thesaurus is mapped to the AAT. It can be used as a terminology look-up service and the concepts/terms are available in Linked Data format (SKOS) for re-use or alignment.
PACTOLS thesaurus[118]	FRANTIQ	A large multi-lingual thesaurus which focuses on antiquity and archaeology from prehistory to the industrial age; terms in French, English, German, Italian, Spanish, Dutch, and (some) Arabic). The thesaurus is maintained by the Fédération et ressources sur l'Antiquité (FRANTIQ), France; it is being used by ARIADNE partner Inrap. ARIADNE has a cooperation agreement with FRANTIQ on the use and further deployment of PACTOLS.
PICO thesaurus[119]	MiBAC-ICCU	A thesaurus of terms related to culture and cultural heritage (Italian and English); a small number of about 200 terms concern archaeology. The SKOS version has been developed by MiBAC-ICCU (with some support by USW) and employed to produce Linked Data of the CulturaItalia portal[120]; Di Giorgio *et al*. (2016) provide details about PICO and Dati.CulturaItalia.
Thesaurus RA (Reperti Archeologici)[121]/*	MiBAC-ICCD	The thesaurus service provides a reworked version of the RA (Reperti Archeologici) thesaurus of the Italian Central Institute for Catalogue and Documentation (ICCD). The thesaurus contains concepts/terms for documenting objects coming from archaeological excavations (Felicetti, Galluccio *et al*. 2016). The reworked version is being curated by MiBAC-ICCU and PIN VastLab. The web-based thesaurus is provided in Linked Data format (SKOS) and aligned with the AAT. It can be used as a terminology look-up service and the concepts/terms may be re-used for interlinking data records.
UK Heritage Data vocabularies[122]/*	FISH	Provides major UK vocabularies (English Heritage, RCAHMS/W and others) in SKOS format and web services which make them

[116] Pelagios: Datasets, http://pelagios.org/peripleo/pages/datasets

[117] iDAI.vocab, http://archwort.dainst.org

[118] PACTOLS (Peuples, Anthroponymes, Chronologie, Toponymes, Œuvres, Lieux et Sujets), http://pactols.frantiq.fr

[119] MiBAC-ICCU: Thesaurus PICO, http://purl.org/pico/thesaurus_4.2.0.skos.xml

[120] CulturaItalia: Dati, http://dati.culturaitalia.it

[121] Thesaurus RA, http://vast-lab.org/thesaurus/ra/vocab

[122] Heritage Data - Linked Data Vocabularies for Cultural Heritage, http://www.heritagedata.org

		programmatically accessible and searchable. These freely available resources have been developed by USW in the UK AHRC funded SENESCHAL project (2013-2014). In ARIADNE the Archaeology Data Services uses several of the thesauri. The vocabularies are maintained by the UK Forum on Information Standards in Heritage (FISH).

4.6.5 Data mining techniques

Indicator defined in the DoW: Data mining techniques established and demonstrated.

Leiden University together with associated partner Free University Amsterdam examined the feasibility to integrate data mining solutions into the ARIADNE e-infrastructure; also involved in some tasks was Athena-RC (ARIADNE 2015c and 2017h). Various methods and techniques have been explored which may be applied for detecting patterns in, and establishing relations between, data of the archaeological domain. The work focused on Semantic Web mining assuming that the ARIADNE data to be mined will adhere, either fully or partially, to the principles of the Linked Data paradigm, i.e. allow exploiting the graph-like structure of such data as well as their semantics. In addition to data mining, the work explored usage-pattern analysis, content linking and information retrieval.

Apart from automated NLP extraction, barely any Linked Data was produced by the ARIADNE project during its first half which could be regarded as a good representative of future ARIADNE Linked Data. Therefore work on data mining first focused on exploratory activities: several Linked Data sets from different archaeological repositories were inspected in order to identify common features which might also characterise future ARIADNE Linked Data. The examined datasets were found to consist largely of flat data structures and descriptive values. The research group concluded that these features need to be taken into account during the development of the data mining solutions for ARIADNE.

Results of a user requirements study indicated the importance of data quality analysis (e.g. which finds are likely to be classified incorrectly) and hypothesis generation (e.g. given attributes-values *a* to *y*, predict attribute-value *z*). Both are areas in which data mining may prove beneficial to the archaeological research community. The research team chose to focus their efforts primarily on hypothesis generation due to 1) its novelty in the archaeological domain, 2) its ability to exploit the semantics of the data, 3) its likelihood of yielding relevant archaeological knowledge, and 4) the ease with which the results can be interpreted. In addition, more traditional data mining methods have been applied as well.

The research team developed the data mining pipeline MINoS (MINing on Semantics) for conducting experiments in the direction outlined. Furthermore, due to the continuing shortage of fine-grained archaeological Linked Data, the research team decided to set up an own Linked Data infrastructure. For this purpose the team converted an XML-based archaeological protocol to RDF, developed a tool to translate protocol instances to RDF, and populated the Linked Data infrastructure with this data. The mentioned archaeological protocol is the Dutch SIKB 0102 protocol. Archaeologists in the Netherlands are required by law to provide documentation of fieldwork according to this protocol.

The Linked Data infrastructure and the data mining pipeline have been completed and trialled, i.e. execution of the pipeline on the infrastructure. Experiments have been conducted on three levels of knowledge granularity. The first level (coarse-grained), addressed by Athena-RC, concerns metadata of the ARIADNE Registry and involved 1) relationship discovery among the authors of OpenAIRE and ARIADNE Reports, 2) the creation and analysis of ARIADNE's author networks, and 3) performing text mining on OpenAIRE publications to link them with ARIADNE metadata or other extracted objects

from the ARIADNE reports. The middle level (finer-grained) concerns RDF extracts from texts such as archaeological reports using a NLP pipeline (extracts provided by USW). The main task at this level was semantic content analysis to inspect commonalities within and between reports. Finally, at the fine-grained level of knowledge, data mining explored the effectiveness of hypothesis generation.

The results confirmed a strong dependence of the usefulness of pattern mining for hypothesis generation on the granularity of knowledge embodied in datasets of Linked Data. For archaeologically relevant results fine-grained semantic data is necessary, which means sufficient complexity of the structural features (i.e. ontologies) and specific information, ideally including literal and numerical values. Linked Data that fulfils these criteria might allow providing relevant results for archaeologists. The research results have been encouraging from a technical perspective but still far from useful from an archaeological perspective. Nevertheless, the domain experts were positively surprised by the range of patterns that were discovered, although most described rather trivial facts. Also, it appeared as challenging to set a good trade-off between being generic (i.e. run any task on any data set) and being specific (i.e. press X to run task Y on data set Z). Overall, there are still some challenges to overcome for the field of semantic data mining to mature and to be of useful for the archaeological research community.

The table below summarises the main activities and results of the data mining work in ARIADNE (see also the description of the data mining demonstrator in *Annex D/D6*):

Activities	***Results***
○ User requirements analysis with regard to data mining	Few archaeologists had experience with data mining, but based on scenarios two areas appeared as relevant: data quality and data transparency, i.e. ensuring the correctness of data and of the information derived thereof. Answers to follow-up questions indicated that the researchers would only consider results of a data mining application if they can easily interpret them, and if the methods employed are understandable and trustable. Based on these findings, the team concluded that Hypothesis Generation (pattern detection) and Data Quality Analysis (anomaly detection) are two data mining tasks that are likely beneficial to the archaeological research community.
○ Investigation of data mining techniques for Linked Data, i.e. review of existing tools	Data mining on Linked Data is still a highly experimental area of research, with few ready-to-us tools available. These tools typically are for power users who understand their internal working, and are therefore unsuited for archaeological researchers. Creating a complete solution for various data mining tasks was not a realistic option within the ARIADNE project. Therefore the team decided to develop a dedicated solution with a narrower scope to serve as a proof of concept.
○ Setting up an environment to facilitate archaeological data mining experiments, incl. framework investigation and creation, data modelling and conversion, and investigating NLP results	A Linked Data infrastructure has been set up and populated with richly linked archaeological data (fine grained knowledge), acquired by XML to RDF conversion of archaeological data based on the Dutch SIKB 0102 protocol. Hereto, CIDOC-CRM and CRM-EH have been used to ensure interoperability with future ARIADNE Linked Data. A second data set used for testing was annotated fieldwork reports (in English), produced by NLP

	(carried out by USW). For this data also CIDOC-CRM and CRM-EH has been employed. In the first data mining experiments the team could improve the data by detecting and removing 'noise' and by performing entity reconciliation.
○ Data mining pipeline and experimentation	An experimental pipeline (MINoS) has been created that outputs potentially interesting hypotheses and their probability based on an input Linked Data set (e.g. SPARQL endpoint) and user criteria (topic of interest, plus optionally the desired sampling strategy, post-processing method, etc.). The data mining pipeline has been wrapped in a simple command-line user interface. Output can be (facet) browsed through interactively, or it can be examined algorithmically using pre-sets (e.g. 'lenient' or 'strict'). The team has run multiple experiments on three data sets of different granularity: ARIADNE Registry metadata, annotated project reports, and rich database extracts from entire archaeological projects. This allowed testing the effects of information granularity on the relevance of the results produced by the pipeline.
○ Evaluation of results	The data mining results were encouraging technically but still far from useful from an archaeological perspective. However, the domain experts were positively surprised by the range of patterns that were discovered, although most described rather trivial facts. In conclusion: in order to derive relevant results very fine-grained and richly interlinked archaeological data is required. Such results could, for example, concern spatio-temporal patterns between archaeological contexts.

4.6.6 NLP techniques

Indicator defined in the DoW: Natural language processing techniques established and demonstrated.

Natural Language Processing (NLP) has been employed for two purposes: extraction, indexing and linking of metadata from unpublished archaeological reports ("grey literature"), and identification of research methods and process models in reports. The work had an experimental character but produced practical methods and tools. The pilot applications that demonstrate new capabilities for making information and knowledge from archaeological reports and other material more accessible are featured in *Annex D/D7 and D8*.

Extraction, indexing and linking of data/metadata from "grey literature"

ARIADNE aims to enable extraction, indexing and linking of data/metadata from not formally published reports of fieldwork, specialist analysis and other "grey literature" by means of Natural Language Processing (NLP). Unpublished reports generated by preventive archaeology in the context of infrastructure development and other land use projects is one of the most important but traditionally difficult to access resources in archaeology.

Project partners explored both machine learning and rule-based NLP methods with the aim to make such research resources more discoverable and useful. Each method has its respective strengths and weaknesses and a major part of the work was to investigate both with regard to their usefulness for the archaeological domain, i.e. reports of fieldwork and analysis of finds in different languages employing special terms (Richards *et al*. 2015).

Machine learning based NLP

Work has been carried out by ADS to develop and evaluate machine learning based NLP techniques and integrate them into a new metadata extraction web application and API. The main purpose of this application is to generate metadata for archaeological documents for resource discovery indexing, where little or no metadata currently exists (ARIADNE 2015d and 2017i).

The developed application takes previously unseen English language text as input and classifies named entities within the text. Selected results can then be used as metadata for the documents. The application allows users uploading documents on a per-file basis or by using batch creation of metadata for multiple files. From a data management perspective however, the large quantities of entities extracted by the named entity recognition (NER) module can be too large to effectively manage. Therefore the annotation tool built into the web application allows users to produce more training data to better train the module.

The web application is being used for the ADS Grey Literature Library, but may be adapted and implemented by other repositories for English language documents. In addition to this application a web service API has been created. This API allows external users submit NER tasks to an ADS server, which then returns a set of terms, including their category and offsets. The API provides a simple HTML interface[123]. Users can include the results in their existing data management systems to improve data search & retrieval.

Rule-based NLP

In the area of rule-based NLP USW's OPTIMA pipeline has been improved and employed. OPTIMA is a semantic annotation system that performs the NLP tasks of Named Entity Recognition, Relation Extraction, Negation Detection and Word-Sense Disambiguation using hand-crafted rules and terminological resources (Vlachidis 2012; Vlachidis *et al*. 2013). The system uses the GATE (General Architecture for Text Engineering) framework, Ontology Based Information Extraction (OBIE) and several other techniques.

Following initial work with English Heritage thesauri also other national vocabularies, Dutch Rijksdienst Cultureel Erfgoed thesauri[124] and vocabularies of the Swedish National Data Service, have been prepared and trialled for the named entity recognition and information extraction tasks (ARIADNE 2015d and 2017i). The results have been encouraging, although there are challenges like the annotation of Dutch compound noun forms that require special attention. Critical for good results in general is the availability of rich and well-structured vocabularies, but even in such cases some modification may be required to conduct NLP with optimal results. The pipelines for English, Dutch and Swedish rule-based NLP, which run on the GATE open source platform, are available for re-use by other developers[125]. Further work is intended to generalise the OPTIMA rule based techniques for grey literature in other European languages.

[123] Archaeology Data Service: NLP API interface, http://ads.ac.uk/nlp/demo.jsf

[124] Rijksdienst Cultureel Erfgoed (Netherlands) thesauri, e.g. Archeologische artefacttypen, see http://data.cultureelerfgoed.nl or http://rce.rnaviewer.net

[125] USW: English, Dutch, Swedish rule-based Natural Language Processing pipelines, https://github.com/avlachid/Multilingual-NLP-for-Archaeological-Reports-Ariadne-Infrastructure

It is worthwhile to summarise also briefly USW's investigation of negation detection in English language archaeological grey literature reports (Vlachidis & Tudhope 2013 and 2015). This work has been carried out with a view to distinguishing a finding of evidence (for example) of Roman activity from statements reporting a lack of evidence, or no sign of Roman remains. Such information is highly relevant for the accurate indexing of documents. The NegEx technique previously used in the biomedical domain (Chapman *et al*. 2001) was adapted to archaeological vocabulary and writing style. Furthermore a particular form of polysemy, which is inflicted by the definition of ontology classes and concerning the semantics of small finds in archaeology, was addressed by a domain specific word-sense disambiguation module. Evaluation on rules targeted at identifying negated cases of four CIDOC-CRM entities gave promising results, delivering 80% recall and 89% precision. The performance of the negation detection module has been compared against a "gold standard" that consisted of 300 manually annotated pages of archaeological excavation and evaluation reports. The NLP modules contribute to the aims of USW's OPTIMA pipeline delivering an innovative application of such methods in the context of archaeological reports for the semantic annotation of archaeological grey literature with respect to the CIDOC-CRM ontology.

Identification of research methods and process models

NLP-based work on the identification of research methods and process models in archaeological reports has been carried out by ARIADNE partners CSIC-Incipit and AIAC in collaboration with researchers of Université Paris 1 Panthéon-Sorbonne / Centre de Recherche en Informatique (Epure *et al*. 2015).

Archaeologists who carried out work in the field and/or laboratory describe the research methodologies they applied in a section of the survey or excavation report. Mining and analysing such descriptions to produce research process models from the textual resources could facilitate knowledge sharing, comparison of approaches and, possibly, improve the team-based research work. Extraction of information on research methods, instrumentation, etc. from publications has also been proposed as a way to enrich the metadata of research data in repositories (Chao 2015). In view of such opportunities, NLP has been employed for discovering described research methods/activities, and relations between them, in archaeological reports.

A novel automatic tool has been developed for this purpose which uses NLP techniques with a focus on the verb semantics for activities mining and a rule-based approach for activity relationships detection (based on i.e. sequence, parallelism and mutual exclusion). The TextProcessMiner tool has been developed in Python employing and evaluating the advantages of different NLP libraries for the purpose (NLTK, Stanford POS Tagger, PyEnchant)[126]. For building a dictionary of verbs for the text mining VerbNet and WordNet has been employed[127]. The innovative NLP approach and TextProcessMiner tool has been demonstrated and evaluated in an archaeological case study that is presented in *Annex D/D8*.

[126] NLTK - Natural Language Toolkit, http://www.nltk.org; Stanford Part-of-Speech Tagger, http://nlp.stanford.edu/software/tagger.shtml; PyEnchant, https://pypi.python.org/pypi/pyenchant

[127] VerbNet, https://verbs.colorado.edu/~mpalmer/projects/verbnet.html; WordNet, https://wordnet.princeton.edu

The table below summarises the main activities and results of the NLP work in ARIADNE (see also the description of the NLP demonstrators in *Annex D/D7 and D8*):

Activities	***Results***
○ Machine learning based Named Entity Recognition (NER) employed in a metadata extraction web application, which includes - an annotation tool for collecting machine training data, - techniques for clustering and ranking the output and generating cluster labels based on the content in respective clusters, - export of selected metadata in a variety of formats, - a NER service API for external users to generate metadata for their data management systems.	Web application developed for the ADS Grey Literature Library; may be adapted and implemented by other repositories for English language documents (code is available) ADS Named Entity Recognition Service API to generate metadata for external systems The demonstrator is featured in *Annex D/D7*; see also the final report on NLP (ARIADNE 2017i)
○ Enhanced rule-based NER and NLP information extraction from archaeological reports (in different languages) with the GATE-based OPTIMA semantic annotation system, including - improved methods for preparing vocabularies in different languages for NLP tasks; customized matching and information extraction for archaeological terms, - pipelines for rule-based NLP (NER, information extraction) of archaeological reports in English, Dutch, Swedish, - NLP results together with extracts from datasets included in a demonstrator of CIDOC-CRM and AAT based semantic integration and cross-searching of information.	Results made available, i.e. NLP pipelines for archaeological reports in English, Dutch and Swedish (run on the GATE open source NLP platform) See the Wooden Material Demonstrator in *Annex D/D4*, and the final report on NLP (ARIADNE 2017i)
○ Identification of research methods and processes in archaeological reports based on automatic, unsupervised NLP techniques, - which employ verb semantics for mining methods and activities described in documents, - a rule-based approach for detecting activity relationships/ models (based on e.g. sequence, parallelism and mutual exclusion), - feasibility demonstrated in a case study of NLP of archaeo-logical information, including evaluation by domain expert	TextProcessMiner tool, developed in Python employing different NLP libraries (NLTK) See also the archaeological demonstrator in *Annex D/D8* and Epure *et al*. (2015) and Gonzalez-Perez *et al*. (2016) The tools of the research proto-type are not yet available for general use

4.6.7 Visual media and landscape services

Indicator defined in the DoW: In the DoW no indicators for this field of research & development have been defined. But visual media such as high-resolution images and 3D models of artefacts and terrains are essential in archaeological research documentation, analysis and interpretation. A high

demand for visual media services and training has been expressed in ARIADNE workshops[128]. Here we present the significant achievements of the project in this field.

Detailed and/or additional indicators	***Results***
○ ARIADNE Visual Media Service: services for easy online publication, visualisation and exploration of high-resolution images, reflectance transformation images (RTI) and 3D models; provided by CNR-ISTI	Available since April 2015, major updates and extensions in 2016 Already over 400 visual media resources uploaded, processed and visualized; 25% open access, others not yet released by on-going projects Average access per month of 700, with large peaks of views in some months (i.e. 1200 in June 2016).
○ ARIADNE Landscape Services: services for processing, management and publication of large 3D interactive terrain datasets; includes processing of DEMs/DTMs, geo-imagery and shapefiles, cloud-based access, 3D interactive visualization through desktop and mobile browsers; provided by CNR-ITABC	Available since Q1 2016, already over 300 datasets (multi-resolution terrain databases) uploaded on the cloud-based platform, processed and results provided in content galleries (detailed figures are given in the service description). Landscape terrains have been produced for research projects and virtual museums as well in training and other events

ARIADNE Visual Media Service

Based on their long-standing expertise and advanced tools the Visual Computing Lab of CNR-ISTI (Pisa)[129] developed the ARIADNE Visual Media Service. The facility provides web-based services for easy publication, visualization and exploration of high-resolution images, Reflectance Transformation Imaging (RTI), and high-resolution 3D models[130]. The services are based on WebGL, SpiderGL and 3DHOP (3D Heritage Online Presenter); for the 3D service in addition to WebGL also a Javascript implementation of the Nexus multi-resolution framework is being employed. The main platform at the base of the ARIADNE Visual Media Service is 3DHOP, an open source solution developed by CNR-ISTI (Potenziani *et al*. 2015).

The ARIADNE Visual Media Service is included in the series of demonstrators that present innovative capabilities and approaches using ARIADNE tools/services, vocabularies and datasets (see *Annex D/D11*). Therefore here we mainly describe the enabled advanced capability and its usage. A content publisher that uses the service is asked only to fill a small form and to upload the raw visual media file. All processing to transform the data in a web-compliant and efficient multi-resolution representation as well as progressive transmission and view-dependent rendering is done by a dedicated server. Content publishers are offered various additional options with regard to presentation, navigation and study, for example for creating sections or taking point-to-point measurements.

[128] cf. ARIADNE: 3D and Visualisation SIG, http://www.ariadne-infrastructure.eu/Community/Special-Interest-Groups/3D-and-Visualization, in particular the documentation of the Special Interest Group meeting 7-8 October 2013.

[129] CNR-ISTI, Visual Computing Lab (Pisa, Italy), http://vcg.isti.cnr.it

[130] ARIADNE: Visual Media Service, http://visual.ariadne-infrastructure.eu

The ARIADNE Visual Media Service development started in 2014 and became publicly available in early 2015; major updates and extensions followed in Q1 and Q3 2016. A large number of visual media resources (>400) have already been uploaded, processed and visualized. On average 700 users (content producers and visitors) access the resources per month, with increasing figures of access since 2016 and large peaks of views in some months (i.e. 1200 in June 2016).

The figures concern the overall data managed. Data owners can select between restricted access options (i.e. a research group) or provide open access. As many service users during ongoing projects chose restricted access only a subset of the material, around 25%, is currently publicly accessible[131]. But confidentiality is an important option when data of on-going, not yet published research is being managed and processed. Therefore the option to keep uploaded data confidential and release it after project completion is offered.

ARIADNE Landscape Services

The Landscape Services (also called Landscape Factory)[132] have been developed by the Virtual Heritage Lab of CNR-ITABC (Rome)[133]. These are web-based services specifically for large terrain datasets generation, dissemination and server-side 3D model processing, employing a cloud-based approach. The solutions are based on open source frameworks and tools such as GDAL, OSGjs, OpenSceneGraph and ownCloud. Data management is performed through a cloud service, allowing fine-grained access control on input/output data, with a focus on input DTMs/DEMs, imagery and shape files.

The Landscape Services are included in the ARIADNE series of demonstrators that present innovative capabilities and approaches enabled by tools/services newly produced or adapted and further developed in the project (see *Annex D/D12*). Therefore here we mainly describe the enabled advanced capability and its usage.

The services offer users different options to control content format, resolution and dissemination segment, and then takes care of geometry/texture compression, multi-resolution, etc. A gallery service allows producers to control, update or delete projects. The front-end for online dissemination provides features such as paged multi-resolution on desktop and mobile browsers for efficient streaming, camera and point-of-view management, multi-texturing and spherical panoramas.

The ARIADNE Landscape Services became available in the first quarter of 2016 and since then have been used for archaeology and heritage research, training and dissemination projects (i.e. virtual museums). Until January 2017 with the services over 300 products (multi-resolution terrain databases) have been produced. These include 23 multi-layered databases, 36 large-scale datasets, 15 IGM datasets and more than 50 annotated terrain databases.

Cloud services are hosting 23 cloud accounts, including personal users (9), staging and training (3) and external research institutions (11). 132 items have been published through cloud-based galleries hosted by the service (about 44%). The products include: more than 30 terrain-DBs produced during training events offered by CNR-ITABC, 32 long-term datasets (included in external ongoing online projects or web-labs, not temporary) and 4 permanent databases utilized for online Virtual Museums, which can be accessed through desktop and mobile devices.

At present the total number of the products on cloud-based user galleries is 60. About 40% of Terrain Databases currently cannot be publicly accessed and browsed because on-going projects typically restrict the access to members of the developer group before they release final products. 54% of

[131] See http://visual.ariadne-infrastructure.eu/browse

[132] ARIADNE: Landscape Services: http://landscape.ariadne-infrastructure.eu

[133] CNR-ITABC, VH Lab, http://www.itabc.cnr.it/pagine/vh-lab-000

working cloud folders (input DEMs/DTMs, orthophotos, shapefiles, etc.) is shared among other partners or external labs for collaborative workflow in landscape reconstruction. The publication storage per cloud user (multiple hierarchical terrain DBs including textures, geometry and metadata) ranges from a minimum of 50 MB to more than 26 GB, including large multi-resolution datasets; the largest database produced by the services is totaling 16 GB, using ~20 cm imagery resolution.

Service contexts and impacts

The services greatly advance the capability of a wide range of users to generate, publish, visualize and study archaeological and cultural heritage content online. The users include research projects, digital archives, e-journals, museums and other heritage institutions. These can make advanced visual media content accessible effectively and useable in novel ways. Some examples can illustrate the benefits and impacts.

Digital humanities projects, archives and e-journals increasingly are looking for possibilities to provide media-rich research publications comprising of the papers and underlying data (evidence) presented as high-resolution 3D models or RTI images. For example, a recent paper in *Internet Archaeology* (Riris & Corteletti 2015) includes RTI images of engravings at a Brazilian rock art site which can be dynamically explored with CNR-ISTI's WebRTIViewer tool. Other archaeological e-journals may follow suit in order to offer also their authors and readership such enhanced publications.

The advanced visual media services/tools are also employed by large research projects. For example, the German excellence cluster project TOPOI (The Formation and Transformation of Space and Knowledge in Ancient Civilizations) uses CNR-ISTI tools for 3D models and other visual media on their research content platform[134]. The TOPOI repository has been implemented to allow publication, review and stable citation of research data such as 3D models. Another example is Zamani, the African Cultural Heritage and Landscape Database[135] which employs an earlier version of 3DHOP. The Zamini project documents heritage monument sites across Africa with 3D models.

Digital archives that hold 3D content will also benefit. The Archaeology Data Service (ADS) has implemented CNR-ISTI's 3DHOP (3D Heritage Online Presenter) on their digital archive to provide a direct support for the access to 3D models (Galeazzi *et al*. 2016). Such models are increasingly being deposited as part of the multimedia files associated to the reports of archaeological excavations. The 3DHOP support allowed ADS to go beyond the conventional approach where interested users had to download the data file and open it with a proper application. Instead users now immediately have an interactive region of the standard ADS web page devoted to the interactive visualization of the 3D model, enabling archaeologist to analyse and study high-resolution 3D models (see the description of this application in *Annex D/D10*).

With regard to museum and community projects the Virtual Museum Valle Calore[136] provides an illustrative example. The museum employed ARIADNE Landscape Services to produce a model of the Hirpinia region (Southern Italy) annotated with texts, images and videos about historical episodes of the area. The virtual museum allows travelling in time and space, learning about history and culture of the territory, guided by protagonists of a twenty-century history to discover secrets of the Hirpinia landscape.

[134] TOPOI collections, http://repository.edition-topoi.org

[135] Zamani (University of Cape Town, Geomatics Division), http://www.zamaniproject.org/index.php/3d-model-viewer.html

[136] As an example: Virtual Museum Valle Calore, http://www.archeovirtual.it/index.php/valle-calore/

4.6.8 Summary of results

CIDOC-CRM extension and mappings

The CIDOC-CRM initially has been developed for the documentation and integration of information about artefacts held by museums and other heritage institutions. The conceptual reference model is an ISO standard since 2006 (ISO21127:2006, renewed as ISO21127:2014). Within ARIADNE several CIDOC-CRM extensions have been created or enhanced which together form the ARIADNE Reference Model. This model is intended to allow the accurate documentation of complex entities and relations of archaeological/scientific observations and analysis, data integration and search, involving reasoning over the distributed data and knowledge. The CIDOC-CRM extensions cover documentation and metadata of archaeological excavations (CRMarchaeo), ancient/historic buildings (CRMba), scientific observations and argumentation (CRMsci, CRMinf), spatio-temporal relations (CRMgeo), and digitisation processes (CRMdig).

Archaeological institutions and projects can now model and integrate better various data resources using the CIDOC-CRM with appropriate extensions. This has been exemplified by mappings of a number of representative databases, including databases of fieldwork, finds and monuments, burials and finds such as coins. A new tool, the Mapping Memory Manager (3M) has been developed by ARIADNE partner FORTH-ICS to facilitate the mapping process and the mapping validation. The web-based application eases the mapping of database schemas to the CIDOC-CRM and selected extensions and may contribute to a wider uptake of the CIDOC-CRM by archaeological institutions and projects.

CHARM models

Researchers of project partner CSIC-Incipit offer the Cultural Heritage Abstract Reference Model (CHARM) which can be used for light-weight modelling of documentation of humanities project, including archaeology. CHARM is expressed in their conceptual modelling language ConML and can be extended to create models which best suit the particular needs of different projects.

In ARIADNE CSIC-Incipit has made available a programming library that can be used with CHARM models, i.e. a modelling engine capable of storing and manipulating ConML models, and examples of such models. The library can be used by software developers who want to create systems for processing archaeological models that are based on CHARM. Models expressed in CHARM can be exported in SKOS or OWL formats and used in Linked Data environments.

Linked Data methods

ARIADNE partners developed and employed Linked Data methods for integration of vocabularies and metadata within the project, and prepared the ground for further linking of resources beyond the ARIADNE pool of resources.

Enabling interoperability and cross-searching of data records from several providers and in different languages based on subjects required mapping of terms of their thesauri (or term lists) to concepts of a common semantic “hub”. Therefore partners had to map subject terms they use in data records to the comprehensive Art & Architecture Thesaurus (AAT) that is available in the Linked Data format SKOS.

Over 6400 mappings were conducted, with mappings by individual partners ranging from below 100 to over 1600 terms. Terms from 27 vocabularies employed by 12 project partners have been mapped to the AAT. For example, the Institut National des Recherches Archéologiques Préventives (Inrap) uses many terms of the PACTOLS thesaurus for the subject metadata of their catalogue of

archaeological reports (DOLIA). In total 1634 PACTOLS terms have been mapped to the AAT. Most partners used the mapping tools provided by USW (which are available open source).

Furthermore, ARIADNE partners produced and helped others to produce vocabularies in SKOS format. Such work has been carried out before, in parallel to, or within ARIADNE. One example of a parallel development in the UK SENESCHAL project is the set of major British Heritage Data vocabularies which are freely available in SKOS format together with web services and wizards for semantic tagging of data. An example of a vocabulary development supported by ARIADNE is the multi-lingual dendrochronology vocabulary in SKOS format of the Digital Collaboratory for Cultural Dendrochronology (DCCD, hosted by DANS).

There is an increasing collaboration on, and sharing of, Linked Data vocabularies, and ARIADNE has contributed to this development. To give but one further example: ARIADNE partners collected and provided the PeriodO service with a set of 659 periods (Paleolithic to Modern times) for 24 European countries. PeriodO assigns unique resource identifiers (URIs) to period information which allows clear and stable linking of data resources which concern the same period. A new service component has been included in the MoRe aggregator of Athena-DCU to attach PeriodO URIs to period information in records collected for ARIADNE. ARIADNE promotes the use of PeriodO to allow wider interlinking of data based on chronologies in Linked Data initiatives.

A section of the ARIADNE portal includes four services of vocabularies in SKOS format that can be used for terminology lookup and aligning and linking vocabulary and data resources. These are the UK Heritage Data vocabularies (mentioned above), the Thesaurus RA (Reperti Archeologici) of the Italian Central Institute for Catalogue and Documentation (ICCD) for objects coming from archaeological excavations (the SKOS version is being curated by MiBAC-ICCU and PIN VastLab), and the iDAI.gazetteer and iDAI.vocab of the German Archaeological Institute (DAI). iDAI.vocab comprises of several thesauri of archaeological terminology in different languages.

Data mining techniques

Pattern mining in Linked Data to support archaeological hypothesis has been trialled by Leiden University together with associated partner VU Amsterdam. The work produced interesting results concerning archaeological data. An examination of (few) available sets of archaeological Linked Data found that these consisted largely of flat data structures and descriptive values. These were unlikely to allow pattern mining for hypothesis generation which archaeologists indicated as relevant in a user requirements study of the research group. The study also found that the archaeologists would only consider results of a data mining application if these can be interpreted easily and the methods employed are understandable and trustable.

To have a more complex set of Linked Data the group generated Linked Data of 73 rich metadata records of archaeological fieldwork documentation according to the Dutch SIKB 0102 protocol. The protocol schema was modelled in CIDOC-CRM, including the English Heritage extension (CRM-EH). Furthermore Archeologisch Basisregister (ABR) thesauri of the Dutch Cultural Heritage Agency have been prepared for use in the transformation of SIKB 0102 XML documents to RDF. A graph database has been set up and populated with the RDF data.

The data has been explored with a data mining pipeline developed by the research group (MINoS - MINing on Semantics). Responding to selected archaeologic topics, methods, etc. the pipeline outputs potentially interesting patterns in the Linked Data. Outputs can be (facet) browsed or examined algorithmically using pre-sets. The research results have been encouraging from a technical perspective but still far from useful from an archaeological perspective. Domain experts were surprised by the range of patterns that were discovered, although most described rather trivial facts.

The results confirmed a strong dependence of the usefulness of pattern mining for hypothesis generation on the granularity of knowledge embodied in datasets of Linked Data. For archaeologically relevant results fine-grained semantic data is necessary, which means sufficient complexity of the structural features (i.e. ontologies) and specific information, ideally including literal and numerical values. Linked Data that fulfils these criteria may allow providing relevant results for archaeologists.

Natural language processing techniques

In ARIADNE Natural Language Processing (NLP) has been employed for two purposes: extraction, indexing and linking of metadata from archaeological reports ("grey literature"), and identification, extraction and analysis of description of research methods and processes in reports. Both machine learning based and rule-based Named Entity Recognition (NER) and information extraction have been experimented with useful results.

For machine learning based NER a metadata extraction web application has been developed. The application includes an annotation tool for collecting machine training data, techniques for clustering, labelling and ranking the NER output, and export of selected metadata in a variety of formats. The application has been developed for the ADS Grey Literature Library, but may be adapted and implemented also by other repositories for English language documents (the code is available). Furthermore ADS provides a NER service API for external users to generate metadata for their data management systems.

Project partner USW developed and trialled NER and information extraction from archaeological reports in different languages with their GATE-based OPTIMA semantic annotation system. The published results include improved methods for preparing vocabularies in different languages for NLP tasks, customized matching and information extraction for archaeological terms, and pipelines for rule-based NLP of reports in English, Dutch and Swedish. The pipelines are available on GitHub and run on the widely employed GATE open source NLP platform. Results of NLP of archaeological reports in the different languages together with extracts from datasets have been included in a demonstrator of CIDOC-CRM and AAT based semantic integration and cross-searching of information.

NLP-based work on description of research methods and processes in archaeological reports has been carried out by ARIADNE partners CSIC-Incipit and AIAC in collaboration with researchers of the Centre de Recherche en Informatique at Université Paris 1 Panthéon-Sorbonne. The experiments employed an automatic tool (TextProcessMiner) that has been developed utilizing Python NLTK and other NLP libraries/components. The tool employs NLP techniques with a focus on the verb semantics for methods/activity mining and rule-based mechanisms for activity relationships detection (based on i.e. sequence, parallelism and mutual exclusion). A demonstration of this NLP approach for the detection, extraction and analysis of method description in archaeological reports, including evaluation by a domain expert, provided encouraging results. The tools of the research prototype are not yet available for general use.

ARIADNE Visual Media and Landscape Services

In ARIADNE's Description of Work no indicators for this field of research & development have been defined. But advanced imaging solutions (i.e. reflectance transformation images) and 3D models of artefacts and terrains are essential in archaeological research documentation and dissemination. A high demand for services that ease the publication and access to such media has been expressed in ARIADNE user workshops and training.

The ARIADNE Visual Media and Landscape Services enable effective generation, publication, visualization and exploration of different media types in high-resolution and different interaction modalities. These services already are being used by many projects:

- The Visual Media Service (CNR-ISTI) for high-resolution images, reflectance transformation images (RTI) and 3D models is available since April 2015. Since then it has been used to process, publish and visualise over 400 3D and other visual media. The service is accessed by several hundred users (data producers and visitors) per month, with increasing figures of access since 2016.
- Launched in spring 2016, the ARIADNE Landscape Services (CNR-ITABC) are being employed by archaeology and heritage research, training and dissemination projects (i.e. virtual museums). Over 300 multi-resolution terrain databases have already been processed and results provided in content galleries on the cloud-based platform.

The services greatly advance the capability of a wide range of users to effectively generate, publish, visualize and study online high-resolution visual content (i.e. 3D models) in novel ways. These include archaeological research projects, digital archives, e-journals, museums and other heritage institutions. For example, digital humanities projects and e-journals increasingly are looking for possibilities to provide media-rich research publications comprising of the papers and underlying data (evidence) presented as high-resolution 3D models or RTI images.

4.7 E-research frameworks and demonstrators

4.7.1 Brief description

The term e-research generally refers to the use of ICT tools/services and data resources to support current and emerging new forms of web-based research. ARIADNE does not prescribe e-research methodologies but aims to support researchers and data managers/repositories with useful services, tools and other resources. The various resources have been described in previous sections.

This section describes a number of demonstrators which present innovative capabilities these resources enable. The demonstrators use different methods, tools/services and vocabularies to enhance the discovery, access to, and (re-)use of data for research purposes. The demonstrators have been developed in different project work packages. This section gives a summary of the demonstrators which are described in greater detail in *Annex D*. Furthermore the section summarises results of a work package that specifically looked into current e-archaeology practices and suggested that one next step of ARIADNE could be to provide Virtual Research Environments (VREs) on top of or related to the ARIADNE e-infrastructure and services.

Indicators defined in the DoW:

- Archaeological e-research frameworks established.
- At least 10 pilot projects completed demonstrating an innovative approach using ARIADNE's tools.

More specific and/or additional indicators: The concept of archaeological "e-research frameworks" requires some explanation also taking account of the focus of the ARIADNE project. This explanation is given in the first section below. The section also summarises the exploration of e-archaeology practices and potential support of such practices by ARIADNE.

4.7.2 Archaeological e-research frameworks and VREs

In archaeology e-research is conducted along the whole research process, in fieldwork (e.g. data capture with various digital tools) and post-fieldwork data processing, analysis and publication of research results. In the successive steps of the research process different e-research frameworks are applied, e.g. when researchers collect data, build and analyse research databases, and present research results online. Moreover different fields of archaeological research use different methods, tools and data resources, for example, studies in classical archaeology versus environmental archaeology.

ARIADNE focuses on enabling discovery, access to and use of data across distributed digital archives. The project does not provide tools/services for capturing data in the field, but supports e-research based on data that is being shared and accessible online. The creation of the ARIADNE e-infrastructure and data portal is an essential achievement in the archaeological domain as it provides a common platform where dispersed data resources can be uniformly described, discovered and accessed. At the same time it is a step towards the even more ambitious goal of providing integrated services and tools capable to support also web-based research beyond data discovery and access. ARIADNE already supports such research in several ways, for example by enabling access to documentation of sites and finds in different countries, which may be used for comparative studies, or providing services for online publication and exploration of visual media (e.g. 2D/3D information objects).

One next step in the future development of the ARIADNE e-infrastructure could be the creation of Virtual Research Environments (VREs), implemented on or related to the ARIADNE data portal. VREs are web-based research environments for domain and cross-domain research which offer generic e-infrastructures services (e.g. data discovery and access) and specific services and tools research communities need for different tasks and types of data. The ARIADNE project has not been charged to develop VREs for researchers in different fields of archaeology, but prepared the ground for such environments based on the e-infrastructure services (i.e. data portal) and additional tools/services for data integration, visualization and (re-)use.

The topic of e-archaeology frameworks and VREs has been explored in ARIADNE's WP17, Innovation in Archaeological Research Methodology (ARIADNE 2017j). The study found that the e-research scenario of VREs has not yet reached the archaeological research community. This is likely to change in the next few years as ever more re-usable data will be shared through digital archives and research tasks can be conducted more effectively online. ARIADNE contributes to this development as the project integrates data from distributed archives and provides a platform and portal on which future VREs can build.

The study results suggest that there is much potential for ARIADNE to provide VREs. But the data infrastructure and services will have to take account of the multi-disciplinarity of archaeological research, particularly different data standards and vocabularies that are being used by the different research specialities. The study also includes a number of case studies. These case studies looked into current practices, existing shortcomings and potential advances of e-archaeology in different research fields or with regard to different data (i.e. physical anthropology, archaeobotany, aerial photography or 3D archaeology).

The WP17 case studies are different from those of the pilot experiments (demonstrators) conducted in other project work packages. These employed the advanced tools/services and datasets developed in ARIADNE to demonstrate their innovative capabilities. The WP17 case studies did not produce technical demonstrators. The focus was on the current state of e-archaeology in different fields of archaeological research, perceived difficulties, and requirements for progress towards innovative e-archaeology, possibly based on VREs.

The portfolio of different pilot experiments (demonstrators) and case studies may promote further research and development for innovative solutions building on the ARIADNE data infrastructure and services. We do not expect, however, that novel archaeological e-research practices will be driven mainly by advances in technological applications, changes in research collaboration (e.g. open sharing of re-useable data) will be just as or even more important.

4.7.3 Demonstrators of innovative capabilities

This section briefly describes the demonstrators which present innovative capabilities enabled by ARIADNE services/tools, models, vocabularies and datasets. 12 demonstrators have been reported, the target was "at least 10". The demonstrators have been produced or enabled based on results of different project work packages and therefore are described in different deliverables. The present report provides descriptions of all demonstrators which are included as *Annex D*.

Most of the demonstrators had an experimental character, i.e. integration of various data based on the extended CIDOC-CRM and other vocabularies, i.e. Art & Architecture Thesaurus, Archeologisch Basisregister (Netherlands), Nomisma ontology (numismatics), Encyclopedia of Life (species names), iDAI.gazetteer, among others. Advanced capability to search data resources and identify relevant related information has been demonstrated. Other demonstrators are close to or already productive solutions that are being used by ARIADNE partners and others (i.e. Visual Media and Landscape Services). The experimental and other demonstrators concern different subjects (i.e. coins, sculptures, wooden material, animal bones, and others) and use different datasets of ARIADNE partners and/or external data resources.

Among the tools and services employed are FORTH-ICS' Mapping Memory Manager (3M); USW's Vocabulary Matching Tool, STELETO (transformation of tabular data) and OPTIMA (natural language processing of fieldwork reports); and 3D models generation, publication and visualisation tools/services (3DHOP, Visual Media Service, Landscape Factory), the latter provided by CNR laboratories (CNR-ISTI, CNR-ITABC).

The intended users of the innovative capabilities are researchers, data managers and integrators, and developers of novel tools and services. For example, research projects can use the 3DHOP-based Visual Media Service to effectively publish and allow exploration of 3D models or Reflectance Transformation Images. These can also be employed by data repositories and e-journals to provide enhanced access to such content.

Some demonstrators focused on or included innovative approaches for (meta-)data extraction based on Natural Language Processing (NLP) techniques and linking of the data based on various vocabularies. This is in line with the overall focus of ARIADNE on making data resources better accessible and more useful. For example Archaeology Data Service developed a web-based application and API for extracting metadata from documents such as fieldwork reports (i.e. ADS Grey Literature Library). The API also other data management systems can use to generate metadata and improve data search & retrieval.

Dataset integrators that need to map subjects of dataset metadata to a common vocabulary will benefit from employing the interactive Vocabulary Mapping Tool. Furthermore use of the CIDOC-CRM and recent extensions is eased by the available Mapping Memory Manager (3M). Expertise in the integration of archaeological data based on vocabularies and Linked Data is currently limited to a small community of researchers and developers. The knowledge base needs to be expanded in order to achieve further progress in the linking of archaeological datasets. Available productive tools can help a larger community of producers with sufficient knowledge in Linked Data principles and methods (cf. ARIADNE 2017f).

4.7.4 Summary of results

E-archaeology frameworks

The creation of the ARIADNE e-infrastructure and data portal is an essential achievement for the archaeological domain as it provides a common platform where dispersed data resources can be uniformly described, discovered and accessed. One next step could be the creation of Virtual Research Environments (VREs) for e-archaeology, implemented on top of or related to the ARIADNE e-infrastructure.

VREs are web-based research environments which offer generic e-infrastructures services (e.g. data discovery and access) and specific services and tools research communities need for different research tasks and types of data. ARIADNE already offers some e-research services like the visual media and landscape services, which enable effective online publication and exploration of images (e.g. Reflectance Transformation Imaging - RTI) and 3D models of objects and landscapes.

The ARIADNE project has not been charged to develop VREs for researchers in different fields of archaeology, but prepared the ground for such environments based on the e-infrastructure services (i.e. data portal) and additional tools/services for data integration, visualization and (re-)use.

The project has studied the current state of e-archaeology in different fields of archaeological research, perceived difficulties, and requirements for progress towards innovative e-archaeology, possibly based on VREs. The study results suggest that there is much potential for ARIADNE to provide VREs. But the data infrastructure and services will have to take account of the multi-disciplinarity of archaeological research, particularly different data standards and vocabularies that are being used by different research specialities.

Demonstrators of innovative capabilities

Project partners developed demonstrators of innovative capabilities that are enabled by ARIADNE services/tools, models, vocabularies and datasets. 12 demonstrators have been reported, the target was “at least 10”; the report includes a documentation of each demonstrator. The intended users of the innovative capabilities are researchers, data managers and integrators, and developers of novel tools and services. Some of the demonstrators had an experimental character, i.e. data integration based on the extended CIDOC-CRM and different vocabularies. These demonstrated advanced capability to search data resources and identify relevant related information. Others are close to or already productive solutions that are being used by ARIADNE partners and others (i.e. Visual Media and Landscape Services).

5 Programme impact indicators and results

The previous chapter presents the results of the impact evaluation based on the set of indicators defined in the Description of Work (Grant Agreement). In addition we take account of a number of expected broader impacts of Integrating Activities stated in the Work Programme 2012 for Research Infrastructures (see *Annex A*). Below we address each of these impacts which can be summarised as follows:

- Structuring impact on the European Research Area (ERA) and coordinated evolution of research infrastructures in the target sector,
- Improved development, access/use and sustainable operation of research infrastructures,
- Cross-disciplinary fertilisations and sharing of knowledge and technologies across fields of research and beyond, including potential for industrial innovation.

These impacts are formulated generically and concern all types of Research Infrastructures, i.e. do not consider essential differences between RIs. Furthermore they relate to broader schemes (e.g. the European Research Area) and concern assumptions, for example, that RIs have the potential to enable cross-disciplinary fertilisation and industrial innovation. Therefore it is necessary to explicate the background of the expectations and underlying assumptions, and show how ARIADNE activities, which relate to a particular type of RI (an e-infrastructure integrating digital archives/repositories), have achieved outcomes in line with the expected impacts. Addressing these outcomes allows highlighting achievements of ARIADNE which are not obvious based on the specific set of indicators employed according to the Description of Work.

5.1 Structuring impact on the ERA and evolution of RIs

***Expected impacts stated in the Work Programme**:* "a structuring impact on the ERA and on the way research infrastructures operate, evolve and interact with similar facilities and with their users. Operators of infrastructures will develop synergies and complementary capabilities in such a way as to offer an improved access to researchers and to develop their innovation potential."

5.1.1 Background

The European Research Area (ERA) initiative has been launched by the European Commission in 2000. The overall aims of the initiative are to co-ordinate and integrate the research and innovation activities and resources at the level of both the Member States and the European Union. Research Infrastructures (RIs) are one pillar of the ERA which is addressed under the ERA priority of optimal transnational co-operation and competition (European Commission 2012: 9-10)[137].

In the context of ARIADNE the main relevant RIs are e-infrastructures, more specifically digital archives and integrating data infrastructure and services. In 2008, the ERA Expert Group highlighted e-infrastructures as essential for the further development of the ERA as they can connect research communities within and across different scientific disciplines, provide online access to research content/data, and networking, computing and other resources (ERA Expert Group 2008: 10 and 24-27).

[137] European Commission, European Research Area: Optimal transnational co-operation and competition, http://ec.europa.eu/research/era/optimal-transnational-co-operation-and-competition_en.htm

In the Communication "A Reinforced European Research Area Partnership for Excellence and Growth" (2012) the European Commission emphasised the importance of research e-infrastructures (eRIs) for e-Science, *"As most knowledge creation and transfer uses digital means, all barriers preventing seamless online access to digital research services for collaboration, computing and accessing scientific information (e-Science) and to e-infrastructures must also be removed by promoting a digital ERA"*. The Commission also stated that it *"will work with e-IRG to promote the alignment of EU and national approaches to eRI development and use"*, and *"propose a roadmap for e-infrastructure development to support e-Science through open access to research tools and resources"* (cf. European Commission 2012a: 9-10 and 13-14)

In the last 10 years considerable investments have been made at the European and national levels in research e-infrastructures for different disciplines. But the e-Infrastructure Reflection Group (e-IRG)[138], since 2003 the main advisory body for European e-infrastructures, notes insufficient coordination among the existing e-infrastructures, and asks all stakeholders to increase coherence of activities such as sharing of ICT and data resources ("e-Infrastructure Commons"). The goals are enabling synergies, cost-effectiveness and sustainability of ICT-enhanced research (e-science) within and across disciplines (e-IRG 2013). The European Science Foundation with regard to e-infrastructures for the humanities notes: *"Digital infrastructures are developing rapidly but unevenly, and there is an urgent need for coordination, standardisation and sharing of experience to prevent unnecessary duplication and the atomisation of good initiatives"* (European Science Foundation 2011: 2).

ARIADNE, as the core EU-funded Integrating Activity project in the field of archaeology, clearly has a role to play with regard to structuring the ERA in this field as well as ensuring a coordinated evolution of e-infrastructures for cultural heritage and humanities research in general. Below we present what ARIADNE has achieved in these regards.

5.1.2 Structuring impact on the ERA in the field of archaeology

ARIADNE's primary objective has been to build an e-infrastructure that allows institutions and researchers share, access and (re-)use data resources as needed for progress and innovation in archaeological research. This core European e-infrastructure for archaeological data and the community built around it foster coordination of stakeholders at the European and national levels, providing direction for and preventing fragmentation of efforts for data mobilisation, sharing and integration.

The European Strategy Forum on Research Infrastructures (ESFRI)[139] in their Roadmap 2016 acknowledges ARIADNE's success in building a (digital) research community, *"quickly growing in the field of archaeology"*, and its role as the leading integrator of archaeological research data infrastructures: *"In the archaeological sciences the ARIADNE network developed out of the vital need to develop infrastructures for the management and integration of archaeological data at a European level. As a digital infrastructure for archaeological research ARIADNE brings together and integrates existing archaeological research data infrastructures so that researchers can use the various distributed datasets and technologies"* (ESFRI 2016: 52 and 175).

The European Archaeological Council (EAC), which comprises of heads of national services responsible under law for the management of the archaeological heritage in the Council of Europe member states, encourages institutions to collaborate with ARIADNE: *"It is essential to encourage the development of European data-sharing networks and projects in the field of archaeology. The*

[138] e-IRG - e-Infrastructures Reflection Group, http://www.e-irg.eu

[139] ESFRI, http://www.esfri.eu

ARIADNE project is an excellent European initiative in this regard and participation in this project should be strongly encouraged" (EAC 2015: 21).

While initially focused on the integration of datasets from ARIADNE partner countries, the project has signed cooperation agreements with archaeological and cultural heritage institutions of other European countries (Denmark, Iceland, Lithuania, Norway and Portugal) as well as involved others on an informal basis, in total 65 institutions (see *Section 4.1.2*). Furthermore, ARIADNE has signed cooperation agreements with institutions and projects in Australia, Israel and the United States, and established liaisons and collaborative activities with others on an informal basis, in total 19 institutions and projects (see *Section 4.1.3*).

5.1.3 Coordinated evolution of research e-infrastructures

Regular coordination among e-infrastructures at the European level is necessary to ensure common policies and interoperability of digital resources as required by researchers in the humanities and heritage sciences, including archaeology. Coordination enables synergies among projects, sharing of resources (data, tools/services), cross-fertilisation and interdisciplinary approaches.

ARIADNE has contributed substantially to the coordination and knowledge exchange among the relevant initiatives for e-infrastructures and digital resources. These initiatives include:

- DARIAH - Digital Research Infrastructure for the Arts and Humanities (ERIC): promotes ICT-supported research and teaching across the humanities and arts. DARIAH has been developed as an ESFRI Roadmap project and became an ERIC (legal entity); EU support is continued through the Humanities at Scale (HaS-DARIAH) project (H2020, 9/2015-8/2017)[140];
- CLARIN - Common Language Resources and Technology Initiative / Infrastructure (ERIC): provides networked access for scholars in the humanities to digital language data and tools of repositories and research centres. CLARIN has been an ESFRI Roadmap project; the CLARIN ERIC and its e-infrastructure are now entirely funded by the participating countries[141];
- Europeana - The gateway to digital content of archives, libraries and museum across Europe: was initially not conceived as an e-infrastructure for research but now includes Europeana Research, which aims to provide tools and services for humanities researchers[142];
- CENDARI - Collaborative European Digital Archive Infrastructure: mobilised and integrated digital archives for the medieval and World War One eras[143];
- IPERION-CH - Integrated Platform for the European Research Infrastructure on Cultural Heritage: develops a distributed European research infrastructure for heritage science, restoration and conservation; it involves 23 partners and builds on outcomes of the projects EU-ARTECH (2004-2009) and CHARISMA (2009-2013)[144];
- PARTHENOS - Pooling Activities, Resources and Tools for Heritage E-research Networking, Optimization and Synergies: builds on existing e-infrastructures of CLARIN, DARIAH, CENDARI and others to enable cross-disciplinary research in the fields of humanities and cultural heritage[145];

[140] DARIAH, https://www.dariah.eu

[141] CLARIN, http://www.clarin.eu

[142] Europeana Research, http://research.europeana.eu

[143] CENDARI (FP7, 2/2012-1/2016), http://www.cendari.eu

[144] IPERION-CH (H2020, 5/2015-4/2019), http://www.iperionch.eu

[145] PARTHENOS (H2020, 5/2015-4/2019), http://www.parthenos-project.eu

- E-RIHS - European Research Infrastructure for Heritage Science: is a new initiative for a distributed RI on the ESFRI Roadmap 2016 aimed to support cross-disciplinary research communities in the documentation, preservation, interpretation and management of cultural and natural heritage. E-RIHS will provide access to scientific infrastructures (analytical physics methods), services/tools, physical collections and repositories for data storage, analysis and interpretation (ESFRI 2016: 52)[146].

The following paragraphs highlight activities which supported the coordinated evolution of e-infrastructures for the humanities and heritage sciences in Europe.

Facilitation and contributions to knowledge exchange

ARIADNE facilitated and contributed to the regular exchange between e-infrastructure projects, for example the following 16 conferences, workshops and meetings. In these events, ranging from large conferences to executive meetings, 800 people (conservative estimate) have been present when partners presented and discussed ARIADNE results with other e-infrastructure representatives:

- *ARIADNE Final Event: Unlocking the Potential of Digital Archaeological Data* (Florence, 15-16 December 2016): representatives of DARIAH-EU and of the new ESFRI project E-RIHS - European Research Infrastructure for Heritage Science gave presentations; also Leonard de Wit, President of the European Archaeological Council, and Felipe Criado-Boado, President of the European Association of Archaeologists gave thoughtful presentations on the current state and prospects of the sector in the coming years.
- *Les rencontres de la TGIR Huma-Num* (Lyon-Ecully, France, 10-13 October 2016): Conference of the French digital humanities infrastructure with a focus on harmonization of open access policies and resources involving representatives of European projects, Huma-Num consortia (i.e. Consortium Mémoire des Archéologues et des Sites Archéologiques - MASA) and digital humanities labs; participation of FORTH-ICS and MiBAC-ICCU.
- *Group of European Data Experts of the Research Data Alliance Europe (GEDE-RDA):* The coordinator of ARIADNE and the humanities e-infrastructures cluster project PARTHENOS, prof. Franco Niccolucci, since July 2016 participates in GEDE-RA[147]. The expert group comprises of directors of research infrastructure projects and aims to provide the European Commission with recommendations on data issues.
- *Italian-German Workshop on Technology and Infrastructures for Cultural Heritage* (Berlin, 12 April 2016): involved representatives of heritage science laboratories and e-infrastructure initiatives (ARIADNE, E-RIHS, IPERION-CH and PARTHENOS), with participation of ARIADNE partners CNR-ISTI, DAI, MiBAC-ICCU and PIN.[148]
- *European Open Science Cloud (EOSC): Connecting users and providers in the EOSC*, third community workshop (Amsterdam, 7 April 2016): Participation of representatives of RI cluster initiatives (ASTERISC, CORBEL, ENVRIplus), EGI.eu, EIROForum (natural sciences research facilities), OpenAIRE and citizen science initiatives (Socientize, Iber civis)[149]. Prof. F. Niccolucci

[146] E-RIHS (expected ESFRI preparatory phase 2016-2019), http://www.e-rihs.eu

[147] Research Data Alliance: Group of European Data Experts in RDA, https://rd-alliance.org/groups/gede-group-european-data-experts-rda

[148] Italian-German workshop on Technology and infrastructures for Cultural Heritage programme, http://ww2.smb.museum/smb/media/news/56895/ProgrammRoundTable_It-Ger_Workshop_Berlin_2016.pdf

[149] European Open Science Cloud - Third Community Workshop, https://indico.egi.eu/indico/event/2875/session/21/?slotId=0#20160407

(PIN) participated on behalf of PARTHENOS (humanities RIs cluster) and ARIADNE. Previously a position paper on the archaeological research community perspective has been provided to the EOSC Stakeholder Workshop in Brussels, 29 November 2015, organised by the High Level Expert Group on the EOSC (Niccolucci & Ronzino 2015).[150]

- *European Research Infrastructures for Heritage Science – E-RIHS 2015* (Florence, June 30 to July 3, 2015), which involved the kick-off of the projects IPERION-CH and PARTHENOS.[151]
- *Research Infrastructures and e-Infrastructures for Cultural Heritage* (Rome, 13-14 November 2014), with participation of CENDARI, CLARIN, DARIAH, Europeana Research, Joint Programming Initiative (JPI) on Cultural Heritage and Global Change[152], and European Commission officials (organised by MiBAC-ICCU and PIN.[153]
- Danish Humanities Research Infrastructures meeting (Aarhus, Denmark, May 2014), participation by ARIADNE coordinator PIN.
- *Second International Conference on Research Infrastructures - ICRI 2014*, Athens, 2 April 2014, participation of Athena RC and PIN.[154]
- *Facing the Future: European Research Infrastructure for the Humanities and Social Sciences* conference (Berlin, 21-22 November 2013), initiated by the Social and Cultural Innovation Strategy Working Group of ESFRI and the German Federal Ministry of Education and Research, and hosted by the European Federation of Academies of Sciences and Humanities (ALLEA) and the German Data Forum. The overall goal of the conference was to outline a roadmap for strengthening European e-infrastructures for the humanities and social sciences; participation of PIN and SND.[155]
- *Data Service Infrastructure for the Social Sciences and Humanities (DASISH)* workshop (Gothenburg, 4-5 October 2013): coordination meeting of infrastructures and projects active in the social sciences (CESSDA, DwB, ESS, InGRID, SHARE) and humanities (CENDARI, CHARISMA, CLARIN, DARIAH, EHRI and ARIADNE, represented by PIN); meeting report DASISH (2013).
- *Cultural Heritage Creative Tools and Archives (CHCTA)* workshop (Copenhagen, 26-27 June 2013): participation of humanities e-infrastructures ARIADNE (represented by ADS), CENDARI, DARIAH, EHRI and other projects (e.g. Europeana Cloud, 3D-ICONS and NeDiMAH Athena-DCU)[156].
- Participation in DARIAH meetings in different countries, i.e. DARIAH VCC meeting (Copenhagen, 6 September 2013), DARIAH Austria (Graz, 20 November 2013), Launch of DARIAH Greece (Athens, Greece, 7 April 2014), DARIAH Ireland meeting (Dublin, 16 December 2015), and others.

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[150] The EOSC initiative is part of the European Commission's package of measures for Digitising European Industry and aims to offer researchers and S&T professionals a virtual environment to store, share and re-use data; this will be underpinned by the European Data Infrastructure (EDI), deploying the high-bandwidth networks and the supercomputing capacity necessary to access and process large datasets stored in the Cloud, cf. http://ec.europa.eu/research/openscience/index.cfm?pg=open-science-cloud

[151] E-RIHS 2015, http://www.parthenos-project.eu/Download/Programma_Evento_HS-2015_06_25.pdf

[152] JPI Cultural Heritage and Global Change (initiative of European ministries and cultural heritage agencies, supported by the FP7 Environment and ERA-Net programmes), http://www.jpi-culturalheritage.eu

[153] Research Infrastructures and e-Infrastructures for Cultural Heritage, conference programme, http://www.otebac.it/internationalconference/index.php?en/1/home

[154] ICRI 2014, http://www.icri2014.eu/programme

[155] Facing the Future conference, http://facingthefuture.gwi-berlin.de; see also Duşa *et al*. 2014.

[156] Cultural Heritage Creative Tools and Archives workshop (CHCTA), https://chcta.wordpress.com/programme/

Cooperation between humanities e-infrastructures

Like the section above the following examples concern integrating e-infrastructures, cooperation between with data archives/repositories are addressed in *Section 5.2*.

***Cooperation between ARIADNE and DARIAH on e-infrastructure development**:* DARIAH ERIC is supported by 17 EU Member States and involves about 120 institutions. The ESFRI Roadmap 2016 acknowledges that *"ARIADNE has strong links with the ESFRI Landmark DARIAH ERIC"* (ESFRI 2016: 175). DARIAH welcomed ARIADNE as an affiliated project and a Memorandum of Understanding (MoU) has been signed for joint activities on e-infrastructure development involving DARIAH Virtual Competency Centres (VCCs). For example, the EGI DARIAH CC project aims to make distributed computing resources available for applications of the digital humanities community (ARIADNE partner KNAW-DANS and the Austrian Centre for Digital Humanities of the ÖAW participate in this project)[157]. A MoU relating to the use of distributed computing resources has also been signed with the DCH-RP project, which has been completed in September 2014[158].

ARIADNE and PARTHENOS, a strong partnership for integrated humanities e-infrastructures: PARTHENOS involves 15 institutions among which are members of the DARIAH and CLARIN e-infrastructures and research organisations such as the Academy of Athens (Greece), INRIA - Institute for Research in Computer Science and Automation (France), International Society for the Study of Medieval Latin Culture (Italy), King's College London (UK) and Trinity College (Ireland). PARTHENOS and ARIADNE are coordinated by the same organisation (PIN Vast-Lab, prof. F. Niccolucci). ARIADNE partners also lead or contribute to work of the PARTHENOS project (CNR-ISTI, CSIC-Incipit, FORTH-ICS, KNAW-DANS, MiBAC-ICCU). Joint activities aimed at the co-ordinated evolution of research (e-) infrastructures include development of common data registration and access services (i.e. alignment of ARIADNE and PARTHENOS dataset catalogue models) and CIDOC-CRM based dataset integration.

***ARIADNE and E-RIHS**:* The ESFRI Roadmap 2016 acknowledges ARIADNE's success in building a (digital) research community, *"quickly growing in the field of archaeology"*, and highlights the project as one background of the E-RIHS - European Research Infrastructure for Heritage Science, newly placed on the Roadmap. *"Heritage Science has brought about the need of structuring the net of infrastructures operating throughout Europe. Fragmentation, duplication of efforts, isolation of small research groups put at risks the competitive advantage of European heritage science research, promoted so well by the unique cultural heritage. The long-term tradition of this field of research, the ability to combine with innovation, and the integration promoted by EU-funded projects such as EU-ARTECH, CHARISMA and IPERION CH in conservation science, and ARIADNE in archaeology represent the background of E-RIHS"* (ESFRI 2016: 52).

***Cooperation with other actors in the environment of research e-infrastructure and data resources**:* To contribute to the coordinated evolution of e-infrastructures for humanities and heritage sciences ARIADNE also cooperates with actors in relevant specific fields, for example:

- *Prehistory:* National Research Centre on Human Evolution – CENIEH, Spain (cooperation agreement)[159]; German Society for Pre- and Protohistory – DGUF, joint organisation of open data sessions at conferences of the European Association of Archaeologists (2014 and 2016)[160];

[157] EGI DARIAH CC is an EGI-Engage project (4/2015-9/2017), https://wiki.egi.eu/wiki/CC-DARIAH

[158] DCH-RP - Digital Cultural Heritage Roadmap for Preservation - Open Science Infrastructure for Digital Cultural Heritage in 2020 (FP7, 10/2012-9/2014), http://www.dch-rp.eu

[159] CENIEH, Spain, http://www.cenieh.es/en

[160] EAA 2014 session: "Open Access and Open Data in Archaeology" (Istanbul, 13/9/2014), http://www.ariadne-infrastructure.eu/Events/EAA-2014-Open-Access-Session2; EAA 2016 session: "Open Access and Open Data in Archaeology: Following the ARIADNE thread" (Vilnius, 1/9/2016), http://www.ariadne-infrastructure.eu/News/Open-Access-EAA-2016

- *Ancient history:* the Pelagios community of over 40 projects in Europe and the United States links content (texts, maps, archaeological records) to ancient places based on the Pleiades gazetteer and Pelagios tools[161];
- *Dendrochronology:* Digital Collaboratory for Cultural Dendrochronology (DCCD)[162], hosted by ARIADNE partner DANS;
- *Cultural chronologies:* PeriodO has established a system for publishing cultural periods which allows linking of datasets based on unique resource identifiers; ARIADNE provided dates for 659 periods (Paleolithic to Modern times) for 24 European countries to PeriodO[163], according to PeriodO director Adam Rabinowitz (Institute of Classical Archaeology, UT Austin) *"a point of reference for the foreseeable future"* (quoted in Fentress 2016);
- *Environmental archaeology:* SEAD - The Strategic Environmental Archaeology Database, University of Umea (cooperation agreement)[164];
- *Epigraphy:* Europeana Network of Ancient Greek and Latin Epigraphy - EAGLE (Memorandum of Understanding; the EAGLE project formally ended in March 2016)[165].

***Contributions to Europeana for Research**:* The Europeana for Research initiative implements tools and services for digital heritage and humanities researchers and collaborates with related e-infrastructures. ARIADNE supports this initiative[166] and partners participated in the Europeana Cloud (eCloud) project which investigated researchers' requirements and developed relevant tools and services, including a Cloud-based infrastructure[167]. The assessment of researchers' needs has been led by Athena-DCU and KNAW-DANS managed the Europeana Research Coordinators Group[168], including representatives from CENDARI, CLARIN, DARIAH, EUDAT[169] and OpenAIRE[170].

Europeana also contains data/content from ARIADNE partners (ADS, CyI-STARC, DAI, Discovery and KNAW-DANS) provided through the projects CARARE[171], 3D-ICONS[172] and LoCloud[173]. Further collabo-

[161] Pelagios, http://commons.pelagios.org; cf. ARIADNE (2015-08-07): ARIADNE at Linked Pasts, http://www.ariadne-infrastructure.eu/News/ARIADNE-at-Linked-Pasts

[162] DCCD, http://dendro.dans.knaw.nl

[163] PeriodO - Periods, Organized, http://perio.do; ARIADNE collection of cultural periods in the PeriodO system, http://n2t.net/ark:/99152/p0qhb66

[164] SEAD, http://www.sead.se

[165] EAGLE (EU, ICT-PSP, 4/2013-3/2016, 19 partners), http://www.eagle-network.eu

[166] cf. Research.Europeana: Related Initiatives, http://research.europeana.eu/work-with-us/related-initiatives

[167] Europeana Cloud - eCloud (EU, ICT-PSP, 2/2013-1/2016), http://pro.europeana.eu/web/europeana-cloud

[168] Europeana Pro: Debut Presentation for Europeana Research Coordinators Group, 3 July 2013, http://pro.europeana.eu/europeana-cloud/europeana-cloud-blog/debut-presentation-for-europeana-research-coordinators-group

[169] EUDAT - European Data Infrastructure (FP7, 10/2011-9/2014; H2020, 3/2015-2/2018), provides common data services, e.g. storage, persistent identifiers, and metadata solutions, http://www.eudat.eu

[170] OpenAIRE, since 2009 assists the EU open access policy and the Open Research Data Pilot (OpenAIRE2020, 1/2015-7/2018), https://www.openaire.eu

[171] CARARE - Connecting Archaeology and Architecture in Europeana (EU, ICT-PSP, 2/2010-1/2013), http://www.carare.eu

[172] 3D-ICONS (EU, ICT-PSP, 2/2012-1/2015), produced and provided to Europeana 3D and other content of archaeological and historic architectural structures, http://www.3dicons-project.eu

[173] LoCloud (EU, ICT-PSP, 3/2013-2/2016), supported small and medium-sized institutions to make digital content available to Europeana, employing cloud services for the data aggregation, http://www.locloud.eu

ration with Europeana may not only benefit researchers but also foster interest of teachers, students and the wider public in archaeology, classical studies and related disciplines.

5.1.4 Summary of results

Structuring impact on the ERA in the field of archaeological research

ARIADNE has been the catalyst for a *collaborative structuring* of the European Research Area (ERA) in the field of archaeology and related disciplines. The overall goal of this structuring is enabling data sharing and integrated access to datasets from institutions located in European countries and beyond, promoting a higher level of transnational cooperative research. More specifically, ARIADNE

- built the European-level e-infrastructure for archaeological data, which provides direction for and prevents fragmentation of efforts for data mobilization, sharing and integration,
- mobilised a large number of stakeholders around the acknowledged e-infrastructure initiative; for example the European Archaeological Council encourages institutions to share data through ARIADNE (EAC 2015: 21), and
- is recognized in the ESFRI Roadmap 2016 as the leading European integrator of digital archives/repositories for archaeological research data (ESFRI 2016: 52 and 175).

Sharing of data, tools and services fosters mutual understanding and collaboration among the involved archaeological research infrastructures, technological research & development centres, academies of science, research associations and public authorities from different Member States. Capitalising on complementary expertise and capacities leverages the innovation potential of the shared e-infrastructure and data resources for the institutions and user communities involved.

Coordinated evolution of e-infrastructures for humanities and heritage sciences

ARIADNE has contributed substantially to the *coordinated evolution* of e-infrastructures and digital resources for humanities and heritage sciences, including archaeology. Coordination activities included clustering and knowledge exchange with infrastructure projects such as CENDARI, CLARIN, DARIAH, Europeana, IPERION-CH, PARTHENOS and the new ESFRI initiative E-RIHS.

The partnership of ARIADNE, DARIAH and PARTHENOS merits to be highlighted with regard to common policies and interoperability of e-infrastructures for the humanities and heritage sciences. The collaboration with Europeana Research, which builds on the massive cultural heritage content of Europeana, may not only benefit researchers but also foster interest of teachers, students and the wider public in content and knowledge of archaeology, classical studies and related disciplines.

The primary focus however is enabling e-infrastructures support ICT-enhanced research in the multi-disciplinary field of archaeological research. In this regard the various collaborations with institutions and projects in areas such as prehistory (CENIEH, Spain; DGUF, Germany), ancient history (Pelagios), epigraphy (EAGLE), environmental archaeology (SEAD, Sweden), dendrochronology (DCCD), cultural chronologies (PeriodO) and others are of vital importance. Coordination and targeted collaboration fosters synergies among projects, sharing of resources, cross-fertilisation and interdisciplinary approaches.

5.2 Improved development, access/use and sustainable operation of RIs

***Expected impacts stated in the Work Programme**:* "a more co-ordinated approach between infrastructure operators, users and public authorities will enable to optimise the development, use and sustainable operation of the identified research infrastructures".

5.2.1 Background

The expected impacts are not stated for specific research infrastructures the development, use and sustainable operation of which the Integrating Activity should help to optimise. In ARIADNE the research infrastructures are digital archives, repositories and databases which the e-infrastructure built by the project connects and integrates in order to offer researchers improved discovery, access and (re-)use of available data for their research.

While *Section 5.1* addressed the coordinated evolution of e-infrastructures in the wider context of ARIADNE, this section focuses on ARIADNE's contribution to the development of archives/ repositories for archaeological data. The main assumption underlying this activity is that optimal curation of archaeological data requires specialised, discipline-based data archives/centres. As Julian Richards, Director of the Archaeology Data Service (UK) explains, *"In many countries it has been assumed that libraries and archives, the traditional custodians of records, will simply take on this additional role. However, few are adequately resourced or staffed to deal with the scale and complexity of digital data, particularly the volume and range of data types produced by the archaeological sector. Several studies have recognised the value of discipline-based repositories in developing stakeholder communities, avoiding fragmentation, and establishing discipline-specific data preservation expertise"* (Richards 2012).

A major concern therefore is the proliferation of data repositories which are being developed by university libraries as well as commercial actors, which both are unlikely to have the expertise necessary for curating archaeological data. University libraries need to serve all disciplines present at the university, and typically only serve the community of affiliated researchers. Data repositories offered by commercial providers (e.g. Figshare[174] and Mendeley[175]) present a similar situation. They invite deposits from all subject areas and ask for only little metadata, which make them attractive for "quick and dirty" depositing of content/data. As many countries in Europe currently lack an archiving centre for archaeological data there is a danger that a lot of data could end up in inappropriate repositories.

Below we present contributions of ARIADNE to the improved development, access to and use of archaeological data archives/repositories, and summarise requirements for their sustainable operation.

5.2.2 Optimised development of RIs

In archaeology an optimisation of the development of research infrastructures is needed particularly with regard to digital archives/repositories. Digital archives for deposit, long-term curation of and access to data provide core services underlying other research e-infrastructures. Access to and (re-) use of archaeological datasets can be improved mainly through central archives (national/ international) of the research community as they allow reducing data fragmentation, which is a major issue addressed by ARIADNE.

[174] Figshare (is run by the Digital Science brand of Macmillan Publishers), http://figshare.com

[175] Mendeley Data (Mendeley is owned by Elsevier) https://data.mendeley.com

The fragmentation of archaeological data poses enormous difficulties to achieve aggregation and integration of data of many projects/institutes at the level of common e-infrastructure and services. Community-level solutions foster common standards and can serve as hubs for data integration and access. The "institutional" model, repositories of single universities or research institutes, provides a local solution for affiliated researchers but offer only limited potential to overcome the fragmentation of archaeological data overall[176].

Current situation

At present there are only few national-level digital archives for archaeological data in Europe and beyond[177]. The existing archives in Europe have been developed by the ARIADNE partners Archaeology Data Service - ADS (UK, established 1996)[178], Data Archiving and Networked Services - DANS (Netherlands, since 2007 includes the E-Depot for Dutch Archaeology)[179], and Swedish National Data Service - SND (which accepts archaeological data since 2011)[180]. ADS and DANS' E-Depot for Dutch Archaeology are the mandated archives for depositing data of archaeological research in the respective country. ARACHNE (IDAI.objects)[181] mainly serves ARIADNE partner German Archaeological Institute (DAI) and the Cologne Digital Archaeology Laboratory (University of Cologne), but a common solution for Germany is being developed (see below).

Many European countries lack a community archive for archaeological data. Not a good solution for overcoming data fragmentation in such cases, especially large countries, would be archaeological data ending up in many general-purpose repositories of universities and other institutions. A look into the OpenDOAR - Directory of Open Access Repositories[182] shows that at present this is not the case. Of the 3316 repositories worldwide covered by OpenDOAR 246 (7.4%) include History and Archaeology content, and only nine of these "datasets" among other content.

We think that the whole domain of archaeological research in Europe will be better off if universities and other research institutions can "outsource" the long-term curation and accessibility of archaeological research data to national or other community-level data archiving centres. In turn, the university departments and institutes could invest more effort in making researchers willing and ready to share their research data. Some local support with regard to data management planning, issues of IPR/licensing, funding of data deposit, etc. will be helpful and could be provided by dedicated staff of research libraries.

New initiatives for community digital archives/repositories in Europe

ARIADNE promotes new initiatives for central, national-level digital archives for the archaeological research community. In Germany such a solution, the IANUS - Research Data Centre for Archaeology

[176] The ARIADNE D2.3 Preliminary Innovation Agenda and Action Plan (November 2015), chapter 5, provides background for this assumption and recommends setting up central, national-level digital archives for archaeological data, http://www.ariadne-infrastructure.eu/Resources/D2.3-Preliminary-Innovation-Agenda-and-Action-Plan

[177] The re3data - Registry of Research Data Repositories recognises as archaeological data repositories the ARIADNE partners: ADS, ARACHNE IDAI.objects, DANS-EASY and SND, and the Open Context and tDAR repositories in the United States; cf. http://www.re3data.org

[178] ADS, http://archaeologydataservice.ac.uk

[179] DANS: E-depot for Dutch Archaeology, http://www.edna.nl

[180] SND, http://snd.gu.se; the Swedish National Heritage Board (SNHB) is working to create a digital archaeology repository and a solution that brings together the complementary strengths of SNHB and SND is being prepared.

[181] ARACHNE (IDAI.objects), http://arachne.uni-koeln.de

[182] OpenDOAR, http://www.opendoar.org

and Ancient Studies[183] is being developed. The initiative is funded by the German Research Foundation and coordinated by ARIADNE partner German Archaeological Institute (DAI). This is a consequent initiative for a common solution in a large country which, hopefully, will be followed by others. Participation in ARIADNE has fostered initiatives in smaller European countries:

- *Austria:* The Institute for Oriental and European Archaeology in collaboration with the Austrian Center of Digital Humanities, both at the ARIADNE partner Austrian Academy of Sciences, develop a data repository; the development is funded under the "Digital Humanities: Long term projects in cultural heritage" programme of the Academy.
- *Hungary:* The Hungarian National Museum has implemented an online database for their field survey, excavation and scientific analysis data[184], and invited archaeologists in Hungary to share their documentation through this database (in addition to the mandatory provision of the documentation to the county museum). The Hungarian National museum also investigates the possibility of digitising pre-digital fieldwork reports which have been provided to the museum for decades. But a national-level digital archive for the long-term preservation of archaeological data is yet to be built in Hungary.
- *Ireland:* The Discovery Programme together with archaeological institutes aims to develop a framework for the archiving of archaeological data, possibly in the Digital Repository of Ireland[185], the national repository for social and cultural data (Corns *et al*. 2014; Corns & Kennedy 2015).
- *Slovenia:* Inspired by the example of KNAW-DANS' E-Depot for Dutch Archaeology, the Society of Slovenian Archaeologists, including researchers of ARIADNE partner ZRC-SAZU (Institute of Archaeology), promotes an initiative for a national archaeological data repository under the Slovenian Ministry of Culture (cf. Corns *et al*. 2014; Štular 2015).

The current situation of country-level archives for archaeological data and ARIADNE's support of initiatives for such archives is best summarised in the following explanation by Benjamin Štular, lead researcher of ZRC-SAZU in ARIADNE: "*Firstly, there are two kinds of countries in Europe; on the one hand there are countries – UK, Holland, Sweden and Germany – that have a digital data archive, and on the other hand there are the majority that do not have it. Secondly, in order to prevent a disastrous loss of digital born data, the have-nots must do something and be quick about it. Thirdly, the latter can only happen by the have-nots learning fast from the haves; and ARIADNE currently presents the best possible opportunity for this to happen"* (B. Štular in Aspöck *et al*. 2016).

Knowledge transfer for state-of-the-art digital archives/repositories

ARIADNE has supported progress towards optimal solutions through fostering knowledge transfer between established data archives/centres and initiatives for centres in other countries. New entries may "leapfrog" to a state-of-the-art solution by learning from acknowledged benchmarks. Beside the ARIADNE data archive partners in Europe such benchmarks in other countries are Open Context (Alexandria Archive Institute, USA)[186], The Digital Archaeological Record - tDAR (Digital Antiquity Consortium, USA)[187], and Federated Archaeological Information Management Systems Project - FAIMS (Australia)[188]. There is a regular knowledge exchange between these digital archives and

[183] IANUS, http://www.ianus-fdz.de

[184] Archaeology Database of the Hungarian National Museum, http://archeodatabase.hnm.hu/en

[185] Digital Repository of Ireland, http://dri.ie

[186] Open Context, http://opencontext.org

[187] tDAR, http://www.tdar.org

[188] FAIMS, https://www.fedarch.org

ARIADNE partners; FAIMS and tDAR are also associated projects of ARIADNE based on cooperation agreements[189].

Conference sessions, meetings and workshops have been organised or attended by ARIADNE partners in order to put the need of data sharing through state-of-the-art archives/repositories and integrating e-infrastructure on the agenda of the research community. This need has been stressed in many ARIADNE presentations. The following are 13 dedicated events, 11 organised by ARIADNE digital archivists and researchers, which have been attended by over 500 people:

- *Preservation and Re-use of Digital Archaeological Data with Open Archival Information Systems* (session) and *Long-term Preservation and Access: Where is an archive for my data?* (round table) organised by ARIADNE partners at CHNT 2016 (Vienna, 16 November 2016); participation of ARCHES - Archaeological Resources in Cultural Heritage, Archaeological Heritage Office Saxony (Germany), ADS, DANS and IANUS.
- *Open Access and Open Data in Archaeology: Following the ARIADNE thread*, ARIADNE session at EAA 2016 Vilnius (1 September 2016); participation of ADS, Athena-DCU, North African Heritage Archive Network (presented by AIAC) and Society of Antiquaries of Scotland.
- *What Do We Mean by Digital Curation?*, symposium at the Annual Congress of the Society for American Archaeology (Orlando, Florida, 9 April 2016): organised by ADS and Digital Antiquity, with participation of digital archives: ADS, Open Context, tDAR - The Digital Archaeological Record, and digital archaeology projects: CyberNABO (linking various data to study the long-term human ecodynamics of the North Atlantic), Digital Index of North American Archaeology, PeriodO – Periods, Organized, SKOPE - Synthesized Knowledge of Past Environments (online data integration tool).
- *Supporting Researchers in the Use and Re-use of Archaeological Data: Continuing the ARIADNE thread*, ARIADNE session at CAA 2016 (Oslo, 30 March 2016), with participation of AIAC (Fasti Online), DAI (Arachne), Inrap (archaeological land-record system) and Directorate-General for Cultural Heritage, Portugal (The Archaeologist Portal).
- *Delavnica arhiviranja digitalnih podatkov*, Ljubljana, Slovenia, 21 January 2016: Data management workshop for archaeologists and heritage professionals, involving representatives of the Ministry of Culture, National Museum of Slovenia, National Archive of Slovenia, Institute for the Protection of Cultural Heritage of Slovenia and several local museums; held at ZRC-SAZU with presenters from ADS and PIN.
- *Datenmanagement in der Archäologie*, Vienna, Austria, 19 January 2016: Data management workshop for archaeologists and heritage professionals, involving representatives of the Austrian Federal Monuments Office (BDA), Austrian Archaeological Institute (ÖAI), ÖAW-OREA and institutes at the Universities of Vienna and Graz, also participants from Hungary; held at ÖAW-OREA with trainers from ADS and PIN .
- *Supporting Researchers in the Use and Re-use of Archaeological Data: Following the ARIADNE Thread*, ARIADNE session at CAA 2015 (Siena, 2 April 2015), with participation of representatives of The British Museum, Historic England, Institute of Archaeology (Iceland), Open Context, ADS and other ARIADNE partners.
- *Save the data! Workshop on Digital Repositories* (Vienna, 2 December 2014), organised by ÖAW-OREA, with participation of ADS, DANS, IANUS (Germany) and the Austrian repositories EPUB.OEAW, GAMS and PHAIDRA[190].

[189] ARIADNE: http://www.ariadne-infrastructure.eu/index.php/Community/Associated-projects

- *Wohin mit meinen Daten?*, DAI-IANUS session at Deutscher Archäologiekongress 2014 (Berlin, 8 October 2014), participation of ADS, African Archaeology Archive Cologne (Germany), DAI/IANUS, DANS, OpenContext (USA), PANGAEA - Data Publisher for Earth & Environmental Science (international / hosted in Germany), TextGrid & DARIAH-DE repository (Germany)[191].
- *Open Access and Open Data in Archaeology*, ARIADNE session at EAA 2014 (Istanbul, 13 September 2014), participation of ADS, Heidelberg University Library / heiDATA repository (Germany), IANUS (Germany) and SITAR - Archaeological Territorial Informative System of Rome (Italy)[192].
- *Online Resources for Archaeological Research*, ARIADNE workshop at CAA 2014 (Paris, 22 April 2014), introduced researchers to online repositories and databases; participation of ADS, AIAC (Fasti Online), DAI (Arachne) and tDAR - The Digital Archaeological Record (USA).
- *Infrastructures and Services for Sharing of Archaeological Documentation*, ARIADNE session at CHNT 2013 (Vienna, 13 November 2013) organised by ÖAW-OREA and SRFG; participation of ADS, DANS, IANUS (Germany), media.REIFF database (Germany) and SND[193].
- *Opening the Past*, MAPPA Conference (Pisa, 13-15 June 2013): MAPPA is an open data repository at the University of Pisa[194]; participation of ADS, DANS and Open Context (USA).

The impact of these events in the archaeological community has been significant. For example, the lead organiser of the international Cultural Heritage and New Technologies (CHNT) conference in Vienna, where ARIADNE has run sessions on data archiving and re-use in 2013 and 2016 acknowledges that ARIADNE *"put the need of effective data management and sharing high on the agenda of our international community of heritage researchers and managers"* (W. Börner, Wien Museum, Urban Archaeology of Vienna; quoted in Aspöck 2016).

To highlight but one example of knowledge transfer and uptake: In 2013 the manager of the IANUS initiative for an archaeological data centre in Germany, Felix Schäfer, spent two weeks at the Archaeology Data Service (ADS) to learn about their data collections management system, workflows and documentation processes. He gained much valuable experience for his work on IANUS:

"As IANUS is still a relative young project to build up a similar discipline specific research data centre for the German archaeological and historical community, IANUS is very happy to see other successful institutions and learn from their experiences (and failures). And what better place to go than the ADS and look over the shoulders of the staff members, asking them numerous questions, inspecting their present and future systems, discussing issues about standards and guidelines and even processing some of my own German-type project collections according to the ADS's workflows and checklists. All this has proven to be very inspiring and informative for me".[195]

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[190] ARIADNE: Save the data: workshop on digital repositories, http://www.ariadne-infrastructure.eu/Events/Save-the-data

[191] IANUS: Wohin mit meinen Daten?, http://www.ianus-fdz.de/projects/veranstaltungen/wiki/Wohin_mit_meinen_Daten

[192] ARIADNE session at EAA 2014, http://www.ariadne-infrastructure.eu/Events/EAA-2014-Open-Access-Session2

[193] ARIADNE session at CHNT 2013, http://www.ariadne-infrastructure.eu/Events/CHNT-Workshop-2013

[194] The MAPPA Open Data repository invites deposits also by researchers not affiliated with the university, http://www.mappaproject.org

[195] ADS SoundBytes (2013-06-17): Felix Schäfer from IANUS visits ADS, http://archaeologydataservice.ac.uk/blog/2013/06/felix-schafer-from-ianus-visits-ads/

End of 2015, as part of the ARIADNE project, three IANUS data curators spent two weeks at ADS to acquire practical experience in the archiving of archaeological data[196]. ADS hosted also a delegation from the Norwegian Museums that are working on a common digital archive solution for their archaeological data. Contributions of ARIADNE partners to the development and dissemination of data archiving and publication solutions are addressed in *Section 5.4.2*.

5.2.3 Improved access to and use of RIs

Accessing and using RIs in ARIADNE concerns datasets held by central digital archives and institutional repositories/databases in different countries and shared through the European-level e-infrastructure. The e-infrastructure services (i.e. data portal) allow data discovery, access to and re-use across the distributed resources. ARIADNE achieved improvements with regard to individual digital archives/repositories as well as the overarching e-infrastructure, which did not exist before.

Some examples of improvements at the level of *individual* digital repositories and databases of archaeological data are:

- *Data resources previously not or only accessible by a few authorised users:* Some have been tentatively "opened up" and data became accessible through ARIADNE; for example records of field surveys in the Romanian part of the Banat region.
- *Use of advanced repository/database systems:* The ZRC-SAZU Institute of Archaeology (Slovenia) transferred the content of the legacy database ZBIVA (Early Medieval sites in the South-Eastern Alps) to the ARCHES platform (Getty Conservation Institute & World Monuments Fund). Thereby more effective access to more data has been enabled. The about 3000 ZBIVA records are included in the ARIADNE registry/portal.
- *Building of new community databases:* The Hungarian National Museum implemented the Archaeology Database, a whole new system initially intended for several hundred own records. Strong promotion by the museum allowed acquisition of nearly 60,000 records (over 891,000 files) contributed by archaeologists across Hungary. The records are included in the ARIADNE registry/portal.

Advances through the enabled *European-level* cross-archive discovery, access and use of archaeological data are:

- This capability did not exist before but has been developed by ARIADNE;
- ARIADNE enables integrated search of shared national/institutional-level archaeological data resources in Europe;
- The data resources have become searchable based on common standards (metadata, vocabulary) and according to core criteria of archaeologists (i.e. subjects, location/map-based and cultural chronology/date ranges), allowing discovery of data from different countries for comparative and other studies;
- Additional mapping of databases to the ISO-standard CIDOC-CRM and ontology extensions created in ARIADNE (i.e. CRMarchaeo, CRMba, CRMsci and others) will allow data integration for advanced search and access, including reasoning over the data.

A survey on the benefits of central data archives in the UK, including the Archaeology Data Service, found that their most widely-agreed benefits relate to research efficiency, i.e. that they *"make research quicker, easier and cheaper, and ensure that work is not repeated unnecessarily"* (RIN 2011:

[196] ADS SoundBytes (2015-12-15): DAI IANUS visits the ADS, http://archaeologydataservice.ac.uk/blog/2015/12/ianus-visit/#more-2218

6). In the case of the Archaeology Data Service the increase in research efficiency of the users has been calculated to be worth at least 5 times the costs of data deposit, operation and use; including other advantages £1 investment in ADS yields up to £ 8.30 return (Beagrie & Houghton 2013).

Similar effects may be achieved by e-infrastructures and services that allow discovery and use of data from many digital archives in Europe, which enables more efficient comparative and integrative research. In the ARIADNE survey on user requirements of 498 responding researchers 74% considered it as very or rather important having easy access to international data(sets), while 72% were less or not satisfied at all with the current situation in this regard (ARIADNE 2014: 100).

While most archaeological researchers arguably work in a national or regional context there is a need for data from research in other countries for comparative analysis, integration and broad synthesis. Researchers would like to carry out investigations that span sites located in different countries (e.g. compare features and items of their site with those of sites in other countries) and place their discoveries in a broader time and space context. Improved access to international data is critical for progress in archaeological research, because many fundamental research questions transcend modern political boundaries and concern regions extending all over Europe and beyond.

5.2.4 Sustainable operation of RIs

Requirements for sustainable operation

ARIADNE investigated the requirements for sustainable operation of data archives which are core elements of e-infrastructure (ARIADNE 2015d: chapter 5), and partners (ADS, DANS and others) shared best practices in the management and operation of data archives with new initiatives of consortium members and other institutions in different countries (see *Section 5.2.2*).

The most effective solution for long-term curation of and access to archaeological data are domain-based central archives, ideally mandated by the main research funding bodies. ARIADNE promotes such archives because they allow advantages such as clear orientation for all stakeholders, formation of centres of expertise for the data of the research field, focused mobilisation of data deposits, cost-effectiveness through economies of scale, among others.

Funding one national-level data centre is very likely a better solution than spreading funds across many hard to sustain data repository projects of individual institutes. According to a study of the Research Information Network (UK) the many benefits of data archives/centres *"for the most part are a result of the data centre's status as a central and sizeable hub within its field"* (RIN 2011: 7).

An important requirement for sustainable digital archives/centres is that they are mandated by research funders, i.e. that researchers are obliged to deposit their data with those archives. For example in the UK, the Archaeology Data Service (ADS) is the mandated archive for data of projects funded by the Arts and Humanities Research Council and the Natural Environment Research Council as well as the archive recommended by the British Academy, Council for British Archaeology, English Heritage and the Society of Antiquaries. In the Netherlands archaeologists since 2007 are obliged to deposit their data with the Data Archiving and Networked Services (DANS), according to the Quality Standard for Dutch Archaeology (Kwaliteitsnorm Archeologie); the DANS-EASY system includes the E-Depot for Dutch Archaeology.

Mandated archives of course devote special attention to measures that promote credibility. Both ADS and DANS (and several other digital archives) are certified according to the criteria of the Data Seal of Approval, indeed the criteria have initially been developed by DANS[197]. State-of-the-art, certified community archives can foster trust in open data sharing as they provide a reliable

[197] Data Seal of Approval, http://datasealofapproval.org

environment for data publication, (re-)use and citation. The publication comes with a price tag, but the costs of post-project data curation and online publication of archaeological projects are only a fraction of the total project costs, between 1-3%, depending on the type of investigation and data generated (cf. Kansa 2012: 14; Kintigh & Altschul 2010: 266).

Another rule of thumb is that the operation of a research data repository costs more than running a typical institutional document repository; indeed the costs are *"an order of magnitude greater"* (cf. the case studies in Beagrie *et al*. 2008: 67-71; see also The Royal Society 2012b). One major cost driver in archaeology compared to other humanities and social sciences data sets is the higher variety and complexity of data formats that need to be ingested and curated (e.g. databases, images, CAD, geodata/GIS and others)[198].

Data acquisition and ingest are the most costly curation activities, while archival storage and preservation activities are a much smaller segment of the overall costs, and likely to decline over time. Keeping the operational costs stable, while curating larger data collections, allows economies of scales (lower per-unit cost). Enhancement of labour-intensive curation activities through streamlining and tool-support (e.g. easy submission of small deposits) can allow significant cost reduction (cf. Beagrie *et al*. 2010: 79-80; Beagrie & JISC 2011). One example of this approach is the ADS-easy service for small-sized project archives of files of a common type[199].

All surveys on open data sharing, including the large-scale ARIADNE survey, show that researchers consider the related effort as a significant barrier (ARIADNE 2014a: 105-106). Specifically, this concerns the effort required to prepare shareable data and detailed data description. Therefore research funders should allow inclusion of the costs of this work in project grants. A project data management plan, as increasingly requested by research funders, is the ideal place to present these costs as well as the expected archive charge for long-term data preservation and access.

Community archives set up for open data curation and access should be stable in the long-term in order to promote trust that the extra effort researchers have to put into sharable, fit for re-use data is well spent. Uncertainties around the sustainability of digital archives may reduce the enthusiasm of the proponents of open data and increase the unwillingness of the yet-to-be-engaged. Commitment for sustained support (10+ years) by the main funding bodies would be helpful in this regard.

Data infrastructure: a good investment

Impact evaluation frameworks for large-scale, single-sited research infrastructures see as an important impact that the construction and operation of such RIs contributes to direct and indirect job generation and some growths in the region where the RI is located. Furthermore they consider that large-scale RIs will supply the regional economy with highly skilled people who contribute to the productivity and innovativeness of businesses and public sector organisations (cf. the most detailed RIFI FenRIAM Guide 2011).

For e-infrastructures such employment effects cannot be argued. The IMPACT study notes: *"Indicators for the impact of e-Infrastructures on economy are difficult to assess as there is no direct reporting of realised competitive advantages or economic growth due to infrastructure access. Also, even if e-Infrastructure projects generate new jobs in their affiliated institutions such numbers are of negligible size"* (Fraunhofer ISI & ZEW 2012: 70).

Indeed, data archives and integrating e-infrastructures do not require a lot of staff (see below), which means that they are a good investment as they provide many benefits. Data infrastructures

[198] Costs4C project: Summary of DANS' Cost Model for Digital Archiving, http://4cproject.eu/summary-of-cost-models/16-community-resources/outputs-and-deliverables/107-cost-model-for-digital-archiving-cmda

[199] ADS-easy: http://archaeologydataservice.ac.uk/easy/

contribute to research efficiency as they enable easy access to data resources, help prevent data duplication and allow re-use of existing data. They also enable potential innovation as researchers can combine and ask new questions of shared data. In short, data that is curated, re-used, combined and analysed with new or enhanced methods gains in value. In the current move towards "open data" it is also important to highlight that state-of-the-art and mandated archives foster trust in open data sharing as they provide a reliable environment for data publication, (re-)use and citation.

These benefits can be achieved with an investment in data curation and access that is small compared to the costs of data generation, analysis and reporting of research projects; in archaeology between 1-3% of the total project costs, depending on the type of investigation and data generated. These are figures for domain-based data archiving and publication platforms (e.g. ADS, Open Context and tDAR). We argue that domain-based data archives at the national level enable research efficiency and other benefits (as mentioned above) as well as cost-effectiveness. Distribution of archaeological data across many institutional repositories would produce an unfavourable situation in several respects: most importantly lack of central access to a large corpus of domain data, but also higher costs and lower quality of service (e.g. university-based repositories need to support all domains of research and may lack expertise for archaeological data).

Mandated domain-based data archive at the national level will allow central curation and access to data based on a small number of specialised staff. For example, the Archaeology Data Service - ADS (UK) has a staff of fourteen, comprising of the director, six digital archivists, two applications developers and one staff member each for administration, collections development, communications & access, editing of the journal *Internet Archaeology*, and European projects (ADS 2015: 38). The IANUS - Research Data Centre for Archaeology and Ancient Studies in Germany (in development) currently has a staff of nine, two project directors (organisation & finance and technology), three data curators, three software developers, and one communications manager[200].

Data Archiving and Networked Services - DANS (Netherlands), which focuses on humanities and social sciences data and provides various online services for the domain has a work force of 43 full-time equivalents (KNAW 2015: 61). About six full-time equivalents can be attributed to the E-Depot for Dutch Archaeology, including curators working specifically on the archaeological data (data acquisition, support of depot users, data management) and general staff categories (IT, software, administration)[201]. Similar staff figures can be found at other archives, for example, tDAR - The Digital Archaeological Record (Digital Antiquity, USA) has a staff of seven comprising of the executive director, the director of technology and one software engineer, three data curators, and one sales & marketing coordinator[202].

If we consider that a central, national-level archaeological data archive requires a dedicated staff of around 10, across the 28 EU member states about 300 people could manage a large part (in small countries maybe all) of the data that is relevant to curate for long-term access. The Discovering the Archaeologists of Europe (DISCO) project estimates *"that approximately 33,000 archaeologists now work across Europe as a whole"* (DISCO 2014: 6). If we fit in 10 people to maintain and further develop the ARIADNE data infrastructure and services, 310 people (around 1% of the domain workforce) could enable access to the archaeological data at the national and cross-archive, European level.

[200] IANUS: Über uns, http://www.ianus-fdz.de/projects/ueber_uns

[201] Information by Hella Hollander, DANS, Head of Data Archive.

[202] tDAR: Staff, http://www.tdar.org/about/staff/

5.2.5 Summary of results

ARIADNE has developed integrated access to existing national-level and other archaeological data archives in Europe, enabling discovery and (re-)use of research data from different countries for comparative and other studies. Indeed, the project has put the sharing of data through digital archives and integrating e-infrastructure on the agenda of the archaeological research community in Europe.

ARIADNE has investigated the conditions for sustainable operation of data archives (e.g. cost structure, centralised service, mandate), and partners have widely shared best practices in their development, management and use, directly as well as through online guides to good practice.

Exchange, discussion and dissemination of consolidated knowledge in digital archiving of archaeological and other humanities data has been enabled in 13 dedicated events, 11 organised by ARIADNE digital archivists and researchers. These events involved leading institutions and projects in the field and have been attended by over 500 people.

ARIADNE also promoted new initiatives for national-level data archives and e-infrastructures for the archaeological research community in several European countries (i.e. Austria, Hungary, Ireland and Slovenia). Furthermore the project fostered knowledge transfer for state-of-the-art archives between established and new initiatives.

Overall ARIADNE has increased the maturity of the discipline with regard to research infrastructures (digital archives and integrating e-infrastructure) and the participation of institutions in the development and sharing of data resources.

5.3 Cross-disciplinary fertilisations

***Expected impacts stated in the Work Programme**:* "a closer interaction between a large number of researchers active in and around a number of infrastructures will facilitate cross-disciplinary fertilisations *[and a wider sharing of knowledge and technologies across fields and between academia and industry]*"; note: the latter part of the statement is addressed in *Section 5.4*.

5.3.1 Background

The Work Programme assumes that research infrastructures can foster cross-disciplinary fertilisations, i.e. interaction and exchange of ideas and knowledge among scholars of different domains of research, promoting cross-domain collaboration for example on societal challenges. The assumption is motivated not only by the idea that cross-disciplinary fertilisation can open up new avenues of research at the intersection of domains, there is also the objective that RIs, which are costly to build and maintain, should ideally serve different research communities. Therefore "multi-disciplinary", "multi-purpose" or "multi-use" are often used characterisations of RI facilities.

The emphasis on cross-disciplinary fertilisation of RIs has been particularly strong in the area of analytical facilities of the natural sciences, e.g. ion beam, spallation neutron and synchrotron light sources, advanced spectroscopy and microscopy, etc. The facilities can be used by many fields of research (including archaeometry) and, therefore, are likely to produce cross-fertilisation effects (cf. ESFRI Roadmap 2016: 146-148).

The quest for cross-disciplinary fertilisation has been expanded to research e-infrastructures and motivated clustering, knowledge exchange and joint development initiatives such as EUDAT (involving a diverse set of domain RIs)[203], DASISH (focused on the ESFRI social sciences and

[203] EUDAT (FP7, 10/2011-9/2014; H2020, 3/2015-2/2018), http://www.eudat.eu

humanities RIs)[204], and recently PARTHENOS for e-infrastructure based cross-disciplinary research in the field of humanities and cultural heritage[205]. Strong cross-disciplinary fertilisation is also expected from E-RIHS, which is a new ESFRI initiative, aimed to support cross-disciplinary research for heritage analysis and conservation, including archaeological heritage (ESFRI Roadmap 2016: 157-158)[206].

A publication on *Research Infrastructures in the Digital Humanities* sponsored by the European Science Foundation highlights as one among several strategic directions, *"The development of RIs that build on existing communities and research questions, in order to facilitate research beyond monodisciplinary interests and across different communities. Infrastructures have the potential to act as ground for cross-fertilisation between the Humanities and other sciences"* (European Science Foundation 2011: 39-40).

The objective of cross-fertilisation resonates very well with the fact that archaeology is a multi-disciplinary area of research that covers several fields of the humanities as well as has close ties with the natural sciences. In a volume of papers on "Archaeology 2.0", Eric C. Kansa of the archaeological data publishing platform Open Context notes: *"Archaeology is an inherently multidisciplinary enterprise, with one foot in the humanities and interpretive social sciences and another in the natural sciences"* (Kansa 2011: 2). Degryse & Shortland (2013) highlight that "*there are very few sciences that have no relevance to archaeology"*, and see an increasing influx of scientific methods in archaeological research.

Indeed, archaeology comprises of different disciplinary contexts: some fields of archaeological research present mainly characteristics of the humanities (e.g. history of arts and architecture, classical studies, medieval history), others lean heavily towards the natural sciences and employ methods of archaeometry or biological sciences, others relate to the earth & environmental sciences, while still others use models and methods of the social sciences (e.g. models of social structure and change and ethnological methods).

To illustrate the case, the figure below is an extract of a larger network of 1554 journals that were co-cited in the Web of Science Web Core Collection index more than 35 times in 10,639 archaeology-related publications between 2004 and 2013 (Sinclair 2014). Beside "archaeological" clusters (e.g. Method and theory, Early Prehistory, Mediterranean and Near Eastern, African, Pacific and Australasian archaeology, Archaeological prospection and remote sensing), the author identified related clusters of publications in Geoarchaeology and earth sciences, Scientific analysis of materials, Life sciences, medical sciences and forensics, and Astrophysics.

[204] DASISH (EU, FP7, 1/2012-12/2014), http://dasish.eu

[205] PARTHENOS (H2020, 5/2015-4/2019), http://www.parthenos-project.eu

[206] E-RIHS - European Research Infrastructure for Heritage Science, expected preparatory phase 2017-2019, http://www.e-rihs.eu

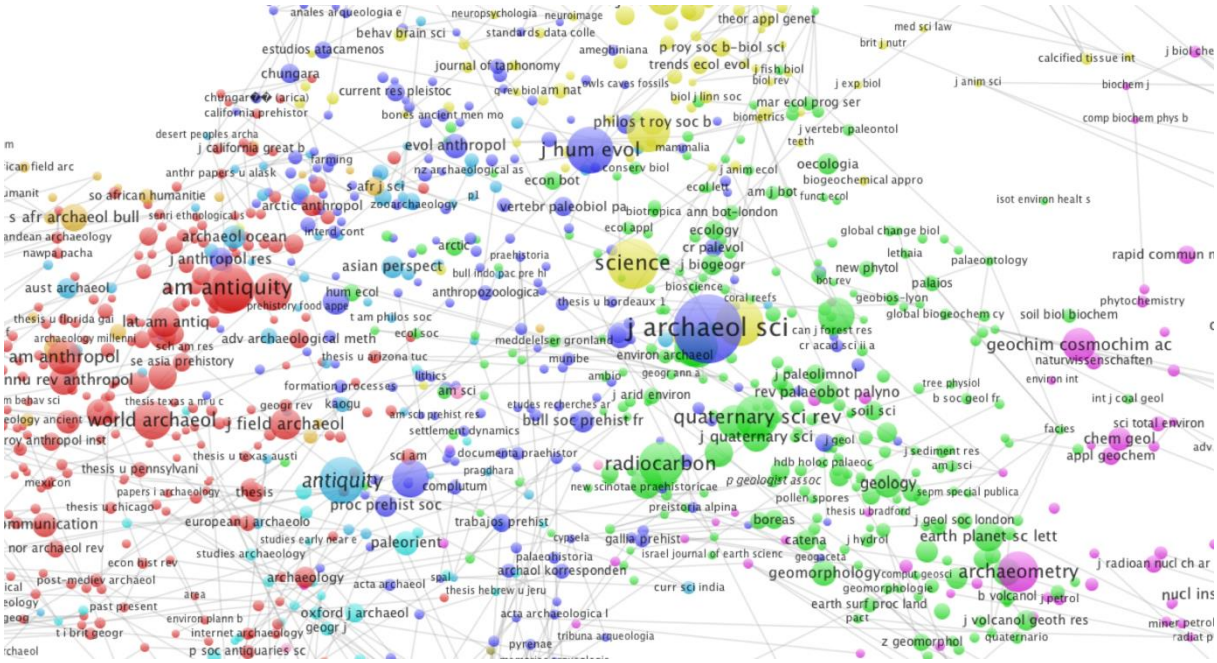

Figure: An extract of a larger figure produced by Sinclair (2014), based on often co-cited journals in over 10,000 archaeology-related publications between 2004 and 2013.

These clusters do not present autonomous, self-contained areas of archaeological research. Rather, they show that scientific studies are published in, and more frequently co-cited by other papers, in relevant journals of the respective fields (e.g. bio-archaeology or geo-archaeology). But the research often has been conducted on the same site/area on which other researchers, using different methods, have published in other journal clusters.

5.3.2 Cross-disciplinary fertilisation in/through ARIADNE

ARIADNE provides a data infrastructure and services that are relevant to all scholarly/scientific domains involved in archaeological research. Sharing and linking through ARIADNE various data has the potential to stimulate cross-disciplinary fertilisation among researchers in fields of archaeological and other humanities research, as well as the humanities and natural sciences (e.g. in projects that involve the use of archaeometry and biological research methods).

Large-scale, single-sited research infrastructures may promote cross-disciplinary fertilisation as scholars of different backgrounds use their special instruments (e.g. synchrotrons, advanced spectroscopy, etc.), exchange ideas and maybe start a joint project. In the context of data infrastructures like ARIADNE cross-fertilisation is fostered by the common objective of various fields of research to share and interlink data.

The aim to integrate knowledge organization systems for this purpose promotes cross-fertilisation with regard to the *conceptual understanding of different fields of research*. A case in point is the CIDOC-CRM, which initially has been conceived for documentation of artefacts held by museums and other heritage institutions. Within ARIADNE the CIDOC-CRM has been extended to cover also research on archaeological sites (excavations), built heritage, spatio-temporal relations, and scientific observations and argumentation in general (see *Section 4.6.2*).

Thus sharing of data by researchers of various domains with the goal to link and integrate the data will induce sharing also of their knowledge, i.e. the frameworks in which such data acquire significance, and consequently stimulate cross-fertilisation among the different fields of research.

A strong cross-fertilisation can also be achieved *between scholars and developers of software tools* for research purposes. This has been experienced in the TNA courses, where young scholars learned how to use different tools, and software developers learned about the requirements of the scholars' projects (see *Section 4.3.2*).

Still an open question is how e-infrastructures and data services can support effectively *inter-disciplinary research online*. The standard answer is virtual research environments (VREs) built on top of generic e-infrastructures. But VREs tend to become domain-specific due to the different requirements of the research communities for specific tools and data, in the field of archaeology for example classical studies versus environmental archaeology.

The potential of building and integrating VREs in the ARIADNE data portal has been addressed by studies in WP17. The study results suggest that there is much potential for ARIADNE to provide VREs. But the data infrastructure and services will have to take account of the multi-disciplinarity of archaeological research, particularly different data standards and vocabularies that are being used by the different research specialities.

5.3.3 Citizens' engagement and transdisciplinary fertilisation

The RI Work Programme considers only fertilisation between researchers of different disciplines (cross-disciplinary fertilisation). Also impact evaluation frameworks for large-scale RIs present a rather limited understanding of citizens' relations and potential engagement with RIs. The RIFI FenRIAM Guide includes an indicator "Activities to foster public awareness" for which a RI would report effects of activities *"to foster public awareness about science in general, its cultural and economic significance for society, as well as the specific scientific and technological activities of the RI and their different types of impacts on the community"*, e.g. RI and RI website visits, events, media coverage (cf. RIFI FenRIAM Guide 2014: 220). A Cost-Benefit Analysis of the Large Hadron Collider at CERN includes benefits to the general public visiting exhibitions at CERN and using its website and dissemination via social media. Under such "cultural effects" also two CERN projects exploiting computing time donated by volunteers to run simulation of particle collisions are considered (cf. Florio *et al*. 2015: 6).

With regard to archaeology we also expect that there will be (future) contributions of the ARIADNE e-infrastructure and services to an increased interest in and appreciation of archaeology and, thereby, an improved standing of archaeological research in society. In particular we consider that access to archaeological "open data" can stimulate a broader engagement of citizens in archaeology. At a general level we may assume that access to various content/data can promote interest in questions of archaeology and heritage by educators, students and the wider public, stimulating study work and visits to archaeological sites and cultural heritage museums.

The term transdisciplinary research concerns the question of how traditional boundaries between disciplines, professions and other communities of knowledge and practice can be overcome. Truly involving citizens in research would mean to go beyond scientific/academic and professional concerns and take full account of citizens' own perspectives, values and understanding of issues (Hirsch-Hadorn *et al*. 2008).

In archaeology this has been discussed widely under the labels of "public archaeology" or "community archaeology". But there appears to be a large gap between what is expected from involving citizens in the research process and what is actually possible in such involvement. As Fairclough notes: *"Attempts to 'involve' or 'engage' the public, to encourage 'participation', to 'share the excitement', seem often to end with 'us' telling them what 'we' have discovered - or persuading them to act as archaeologists in an approved manner. All well and good, but is it enough?"* (Fairclough 2014: 5).

Many papers now address "crowd sourcing" and "open data" as ways to engage non-experts in archaeology (e.g. Beale 2012; Bevan 2012; Bonacchi 2012; Morgan & Eve 2012; Richardson 2013). Most of the examples however present a one-way model of participation, especially those which invite citizens to transcribe historic material in online environments which have been built for this purpose[207]. Other projects have involved citizens in the creation of 3D objects of heritage objects and buildings[208].

With regard to the ARIADNE data infrastructure and services it is too early to evaluate if they allow non-experts a deeper involvement in archaeology. In general we assume that data from archaeological research is not something many non-experts may easily understand and use for own research work ("citizen science"). Therefore some mediation by archaeologists within public or community archaeology projects may be necessary. A future evaluation of the ARIADNE data infrastructure and services after some years of regular operation could look for cases where they have been used in such projects and in citizens' own investigations.

5.3.4 Summary of results

Archaeology is a multi-disciplinary discipline that spans several fields of the humanities (e.g. history of arts and architecture, classical studies, historical archaeology, ethnography and others) as well as has close ties with the natural sciences (e.g. projects that use archaeometrical, biological and environmental research methods).

ARIADNE provides data services relevant to all scholarly/scientific domains involved in archaeological research. Sharing and linking through ARIADNE of data sets which contain various data can stimulate cross-disciplinary fertilisation among researchers of different domains both within and beyond the humanities. ARIADNE researchers also have explored the potential of virtual research environments (VREs) for archaeological projects in view of enabling domain and cross-domain integrative research.

Cross-fertilisation has been promoted with regard to the conceptual understanding of different fields of research through the application of knowledge organization systems (thesauri, ontologies) for the linking and integration of data resources. Especially the extended CIDOC-CRM (ARIADNE Reference Model) has the potential to stimulate cross-fertilisation among different fields of research.

ARIADNE also fostered cross-fertilisation between scholars and developers of software tools for research purposes. This has been experienced in the trans-national study visits and courses where scholars learned how to apply various tools, and software developers learned about the requirements of the scholars' projects.

The evaluation has also considered the potential of the ARIADNE data infrastructure and services for promoting interest in questions of archaeology and heritage by educators, students and the wider public, maybe stimulating study work and visits to archaeological sites and cultural heritage museums. Access to archaeological "open data" may foster a broader engagement of citizens in digital archaeology.

However, it has been concluded that it is too early to evaluate if ARIADNE allows non-experts a deeper involvement in (online) "public archaeology" or "community archaeology" projects. A future

[207] For example, Ancient Lives (Egyptian papyri), http://ancientlives.org; MicroPasts (museum object cards that document Bronze Age metal artefacts), http://micropasts.org; UrCrowdsource (field notes, letters, reports, etc.), http://urcrowdsource.org

[208] For example, HeritageToGather, http://heritagetogether.org; ACCORD - Archaeology Community Co-Production of Research Data, https://accordproject.wordpress.com; also a MicroPasts project invited volunteers to "photo-mask" artefact images which allows to produce 3D models (Bonacchi *et al*. 2014).

evaluation of the ARIADNE data infrastructure and services, after some years of regular operation, could look for cases where they have been used in such projects and in citizens' own investigations.

5.4 Sharing of knowledge and technologies

***Expected impacts stated in the Work Programme**:* "a closer interaction between a large number of researchers active in and around a number of infrastructures will facilitate *[cross-disciplinary fertilisations and*]* a wider sharing of knowledge and technologies across fields and between academia and industry"; "also contribute to increase the potential for innovation of the related research infrastructures, in particular by reinforcing the partnership with industry, through e.g. transfer of knowledge and other dissemination activities, activities to foster the use of research infrastructures by industrial researchers, involvement of industrial associations in consortia or in advisory bodies" *[*note: cross-disciplinary fertilisations are addressed in Section 5.3]*.

5.4.1 Background

The Work Programme considers two fields of innovative impact with regard to the sharing of knowledge and technologies that are produced in the context of Research Infrastructures (RIs): across fields of research, and in related industries. Obviously the emphasis of the Work Programme is on the participation of industrial actors in the development of RIs and the potential of RIs to promote innovation in related industries.

The issue with this expectation is that the Work Programme applies it to all RIs without considering differences in terms of scientific domains and types of RIs. In practice, however, participation of industrial actors in social sciences and humanities RIs, and potential for industrial innovation from such RIs, is rather unlikely. With regard to the different types of RIs the notion of industrial innovation of the Work Programme is mainly informed by research facilities in the fields of natural and life sciences. In these fields industrial providers are sometimes involved in the construction and upgrade of RIs (e.g. procurement of innovative instrumentation) and industrial researchers and developers are among the users of facilities such as specialised laboratories (EIRIISS 2013).

The EPIRIA evaluation of the FP7 Research Infrastructure programme found *"that the impact on industry as user is limited due to the low participation numbers in the programme – both as participant and 'external' user of the RI"* (EPIRIA 2014: 60). For example, for the 1559 participants of Integrating Activities in the RI programme 2006-2012 the breakdown in percent is as follows: 90% Research Organisations, 5% Public Bodies, 3% SMEs and 2% Large Enterprises. In the area of "horizontal" e-Infrastructure projects with 1013 participants the presence of industrial actors was somewhat higher: 83% Research Organisations, 6% Public Bodies, 6% Large Enterprises and 5% SMEs (EPIRIA 2014: 60).

The category of horizontal e-Infrastructures includes Communication Networks (e.g. GÉANT and National Research and Education Networks), Computational Infrastructures (e.g. Grid-based e-Infrastructure and HPC such as EGI.eu and PRACE), Data Infrastructures & Services (typically for large domains such as Energy, Earth & Environmental and Life Sciences), and Virtual Research Communities/Environments. Industry participants in these fields were predominantly suppliers, e.g. software and middleware systems developers, in addition to telecommunication companies (cf. EPIRIA 2014: 8-9 and 27).

In the distinction between Integrating Activities (for particular scientific fields) and horizontal e-Infrastructures (services for all or large disciplinary domains), ARIADNE is located in the first category, as an Integrating Activity for archaeological datasets which required the building of data infrastructure and services. In this endeavour ARIADNE, like many other projects, entrusted research

organisations and digital archives rather than businesses of the ICT sector with the development of the technical solutions and services. These research organisations and archives have a track record in implementing data services for the cultural heritage sector.

But ARIADNE shared knowledge and technologies widely across relevant fields of research and the project outcomes are of course also available to public sector organisations and businesses that are active in these fields (e.g. archaeology and cultural heritage management) or interested in the technical solutions in general.

5.4.2 Sharing of knowledge and technologies across fields of research

ARIADNE has shared new knowledge and results of technological development widely across relevant fields of research, including the multi-disciplinary field of archaeology, cultural heritage and humanities research, and heritage sciences (e.g. archaeometry and heritage conservation). The knowledge and technology transfer includes sharing of models, tools and services, training for tool/service users, presentations and publications on use cases and research results, and provision of online guides to good practice.

Some figures can illustrate the intensity of the knowledge transfer: project partners gave presentations at 218 events with 9600 participants (conservative estimate), provided training opportunities (TNA study visits, short courses, tutorials) for over 500 participants, published 86 papers in journals, conference proceedings and other publications on ARIADNE topics, use cases and research results (see the *Sections 4.2.2, 4.3* and *4.2.6*).

This section focuses on the models, tools/techniques and services that have been developed and are being shared by project partners through ARIADNE. We first briefly address the main areas in which ARIADNE partners have developed and shared new knowledge and technologies, followed by a tabular overview of the resources.

Know-how and technologies for data archiving and publication

Knowledge exchange and transfer for state-of-the-art digital archives/repositories is addressed in *Section 5.2*. In many events and other dissemination activities ARIADNE has put the need for data sharing through state-of-the-art archives and integrating e-infrastructure on the agenda of the research community. Project partners have shared widely good practices in the development and operation of digital archives. In particular, ARIADNE has fostered knowledge transfer between established data archives/centres and initiatives for centres in other European countries, so that new entries may “leapfrog” to a state-of-the-art solution by learning from acknowledged benchmarks.

In addition to this knowledge transfer we note some contributions of ARIADNE partners to the development and sharing of data archiving and publication solutions:

- ARIADNE partners joined the community around the ARCHES open source platform for cultural heritage inventory and management. The platform is being developed jointly by the Getty Conservation Institute and the World Monuments Fund[209]. In July 2014, PIN researchers participated in an ARCHES community workshop in Apsley, England and thereafter, in November 2014, a workshop with the developer team was held at PIN in Prato, Italy.
- OEAW-OREA tried using the ARCHES system for their “Digitizing Early Farming Cultures” project which aims to harmonize and integrate data from research on neolithic and chalcolithic sites in Greece and Anatolia. But the research group found that ARCHES was not an optimal solution for this kind of project (Aspöck & Masur 2015).

[209] ARCHES, http://archesproject.org

- ZRC-SAZU has successfully moved their database ZBIVA - Early Medieval sites in the South-Eastern Alps to the ARCHES platform[210], and provides feedback on the implementation to the ARCHES developers.
- DAI provides mirror hosting and back-up for the Open Context data publication platform (Digital Antiquity consortium, USA), employs the platform for own data dissemination, and supports the expansion of its capabilities for data visualization and analysis[211].
- DANS makes the repository software of the Digital Collaboratory for Cultural Dendrochronology (DCCD) available open source to promote sharing and integration of dendrochronological data[212]; the repository employs the Tree-Ring Data Standard (TRiDaS) and allows for conversion of other widely-used data formats;
- DANS collaborates also with the publications management and sharing platform Mendeley which since November 2015 offers users depositing data free of charge in Mendeley Data[213]; DANS provides the long-term data archiving service for the Mendeley data repository (DANS-KNAW 2015; Hoey 2015).

Know-how and technologies for integrating e-infrastructure and services

ARIADNE builds on data archives/repositories that specialise in the curation of archaeological and other cultural heritage data, and provides an integrating data infrastructure and services that allow cross-archive search, access and other services. Various standards and technologies have been employed for providing the data infrastructure and services (see Aloia *et al*. 2017 for a comprehensive overview). Here we highlight the most important standards and technologies, especially those which have been adapted and/or improved by the project.

Data registry

ARIADNE addressed the issue that archaeological datasets often remain isolated, not interoperable and therefore not searchable in an integrated way. In order to overcome this fragmentation ARIADNE has enabled institutions large and small to describe their digital resources and associated services in a central registry[214]. The description of the resources and services follows a common data model, the ARIADNE Catalog Data Model (ACDM)[215]. The ACDM is based on the W3C recommended Data Catalog Vocabulary - DCAT[216], adapted for the description of archaeological data resources (Aloia *et al*. 2014). Most users of DCAT are national catalogues and portals of public sector datasets, which use a DCAT Application Profile and are harvested by the European Data Portal[217]. ARIADNE provides an example for the adaptation and use of DCAT for datasets of a domain of research.

Data aggregation

ACDM compliant records are aggregated and ingested into the metadata repository of the ARIADNE data registry. For this process the MoRe (Metadata & Object Repository) aggregator is being

[210] ZBIVA, http://zbiva.zrc-sazu.si

[211] Alexandria Archive (2015-08-11): Open Context on the DAI Cloud, http://alexandriaarchive.org/tag/mirror-hosting/

[212] DCCD software on Github, https://github.com/DANS-KNAW/dccd-webui

[213] Mendeley Data, https://data.mendeley.com

[214] ARIADNE Registry, http://registry.ariadne-infrastructure.eu

[215] ARIADNE Dataset Catalogue Model (ACDM) support website, http://support.ariadne-infrastructure.eu

[216] W3C (World Wide Web Consortium) Recommendation (16 January 2014): DCAT - Data Catalog Vocabulary, http://www.w3.org/TR/vocab-dcat/

[217] Semic.eu: DCAT-AP, https://joinup.ec.europa.eu/community/semic/og_page/dcat-ap

employed, which is provided as a Cloud-based service[218]. MoRe has been developed and applied by ARIADNE partner Athena-DCU in previous cultural heritage projects (e.g. CARARA and LoCloud). MoRe employs an OAIS-compliant repository engine and a modular services architecture that supports various manual and semi-automated digital curation tasks. Users can harvest metadata from multiple sources in multiple schemas (e.g. Dublin Core, CARARE, Encoded Archival Description, Europeana Data Model, LIDO); validate, clean and normalize large amounts of content, enrich and/or transform it into a common schema, and publish it to multiple targets, e.g. OAI-PMH 2.0 or a RDF triple store.

Interoperability standards and tools

The metadata of the ARIADNE data providers have become integrated and searchable on the ARIADNE data portal according to the criteria "what" (subjects), "where" (location) and "when" (chronology/date ranges). The portal puts into operation a proof of concept exemplar developed some years ago under the ARENA project (Kenny & Richards 2005).[219] In addition to searching the ARIADNE data catalogue for specific topics through a full-text search interface, users can also visualize and filter the contents along geospatial, temporal and thematic dimensions, thereby allowing them to explore and dig into the available information resources. To allow such searching different standards and techniques have been employed:

- "What" (subjects): Mapping terms/concepts used by data providers from their thesauri or term lists to the Art & Architecture Thesaurus (AAT) as a common semantic backbone. For such mappings ARIADNE partner USW provides a lightweight browser based application, the interactive Vocabulary Matching Tool[220].
- "Where" (location): Geo-spatial coordinates have been converted to WGS84 format or, where only place names were available, coordinates produced via the GeoNames gazetteer for modern places.
- "When" (chronology/date ranges): ARIADNE partners produced a set of cultural periods from the Paleolithic to Modern times for 24 European countries which is employed in the ARIADNE data portal. The set has been incorporated in the PeriodO system which allows stable linking of the chronology information based on persistent URIs[221]. Through the PeriodO system also other projects can use the set of cultural periods.

The CIDOC Conceptual Reference Model (CIDOC-CRM) has been extended to allow addressing better the complexity of archaeological data integration. A new tool, the Mapping Memory Manager (3M)[222] has been developed by ARIADNE partner FORTH-ICS to facilitate the mapping of databases to the ARIADNE Reference Model. The enhanced capability of the model has been confirmed in application pilots.

Natural Language Processing (NLP)

ARIADNE partners applied different NLP methods and techniques to make reports of archaeological fieldwork, specialist analysis and other material better accessible and useful. This included metadata extraction from "grey literature" for search questions such as "what" (monument type, artefact,

[218] MoRe (Metadata & Object Repository) aggregator, http://more.dcu.gr

[219] ARENA - Archaeological Records of Europe Networked Access (EU Culture Programme, 2001-2004), http://ads.ahds.ac.uk/arena/

[220] Vocabulary Matching Tool, http://heritagedata.org/vocabularyMatchingTool/

[221] ARIADNE collection of cultural periods in the PeriodO system, http://n2t.net/ark:/99152/p0qhb66

[222] Mapping Memory Manager (3M), http://www.ics.forth.gr/isl/3M

material, etc.), "where" (location, archaeological context), and "when" (age/period, dates); also information about research methods and processes have been extracted and analysed.

NLP is a well-established field of research and development with numerous solutions and productive applications. ARIADNE work in this field employed different frameworks such as GATE (General Architecture for Text Engineering) and Python NLTK (Natural Language Toolkit), and investigated various methods for improving NLP tasks specifically for cultural heritage and archaeology content. The OPTIMA semantic annotation system, developed by USW since 2007, is among the leading rules-based solutions in this field. It performs the NLP tasks of Named Entity Recognition, Relation Extraction, Negation Detection and Word-Sense Disambiguation using terminological resources of the domain.

Arguably the most important advance within ARIADNE has been in the investigation of what can be achieved by, and what still needs to be improved for, employing archaeological terminologies in different languages. In this context it is also important to note that for taking advantage of NLP some archaeological communities in Europe will have to invest more effort in developing their vocabularies.

Visual Media and Landscape Services

Project partners have developed advanced online services for visual media and landscapes. The Visual Computing Lab of CNR-ISTI has implemented web-based services for publication, visualization and exploration of 3D models, Reflectance Transformation Imaging (RTI), and other high-resolution images[223]. CNR-ITABC developed web-based services that support generation and management of 2D/3D interactive WebGIS environments for large 3D terrain and landscape models[224]. The services and their usage are described in greater detail in *Section 4.6.7*.

Employing such services/tools in research projects, for content deposited in digital archives and/or published in e-journals greatly advances researchers' capability to publish, access, visualize and study archaeological and other cultural heritage objects online. For example, CNR-ISTI's 3DHOP (3D Heritage Online Presenter) for interactive presentation of high-resolution 3D models has been implemented by the Archaeology Data Service to allow researchers explore 3D models deposited in their digital archive (Galeazzi 2015; Galeazzi *et al*. 2016). Reflectance Transformation Imaging (RTI) allows inspecting objects in rich detail. A recent paper in *Internet Archaeology* (Riris & Corteletti 2015) includes RTI images of engravings at a Brazilian rock art site which can be dynamically explored with the WebRTIViewer developed by CNR-ISTI[225].

We expect a wide adoption of these new ways of making cultural heritage content available for research and dissemination. Such enhanced publications are of particular interest to online publishers and of course not limited to the domain of cultural heritage.

Tabular overview of shared models, tools/techniques and services

The table below gives an overview of models, tools/techniques and services which are being shared by partners through ARIADNE. It should be clear that ARIADNE's focus is on specific needs and requirements of archaeology and cultural heritage. Therefore most of the items have been specifically developed for users of this sector while others may be of interest to users also from other sectors.

[223] ARIADNE: Visual Media Server, http://visual.ariadne-infrastructure.eu

[224] ARIADNE: Landscape Services: http://landscape.ariadne-infrastructure.eu

[225] Visual Computing Lab (CNR-ISTI, Pisa): WebRTIViewer, http://vcg.isti.cnr.it/rti/webviewer.php

Technology	*Tool/service*	*Developer*	*Software / service*
Data modelling			
CIDOC-CRM	New and enhanced extensions to the ISO standard CIDOC-CRM, integrated in the ARIADNE Reference Model; novel tool for mapping databases to the model (see 3M below)	FORTH-ICS	www.ariadne-infrastructure.eu/Resources/Ariadne-Reference-Model
ConML	Conceptual modelling language specifically for the humanities and social sciences	CSIC-Incipit	www.conml.org
CHARM	Cultural Heritage Abstract Reference Model: based on ConML and designed to be used by researchers and practitioners in archaeology and heritage and extended to meet their particular needs	CSIC-Incipit	www.charminfo.org
CHARM library	Programming library for CHARM models, i.e. a modelling engine capable of storing and manipulating ConML models, and examples of such models. Models expressed in CHARM can be exported in SKOS or OWL formats and used in Linked Data environments	CSIC-Incipit	http://www.conml.org
Data conversion and mapping			
Data conversion	STELETO is an open source, cross-platform application for conversion of tabular data via a custom template into other textual formats	USW	Application/code on Github[226]
Data conversion	Linked Data translation for the Dutch SIKB archaeological protocol 0102	VU Amsterdam	Application/code on Github[227]
Vocabulary mapping/ matching	Interactive Vocabulary Matching Tool; in ARIADNE several "local" subjects vocabularies of partners have been mapped to the Art & Architecture Thesaurus	USW	Web application[228] Application/code on GitHub[229]
CIDOC-CRM mapping	Mapping Memory Manager (3M); facilitates the mapping of databases to CIDOC-CRM and the mapping validation; several databases have been mapped and the results have been used in pilot demonstrators	FORTH-ICS	Web application[230] Application/code on GitHub[231]
Chrono-logies	ARIADNE partners produced a set of cultural periods from the Paleolithic to Modern times for 24 European countries which is employed in the ARIADNE data portal. The set is incorporated in the PeriodO system which allows stable linking of the chronology information based on persistent URIs. Through the PeriodO system also other projects can use the set	ARIADNE partners and PeriodO	ARIADNE collection of cultural periods in the PeriodO system[232]
Natural Language Processing (NLP)			
Machine	Metadata extraction application that identifies and	ADS	Metadata extraction

[226] http://github.com/cbinding/STELETO/

[227] https://github.com/wxwilcke/pakbon-ld

[228] http://heritagedata.org/vocabularyMatchingTool/

[229] https://github.com/cbinding/VocabularyMatchingTool

[230] http://www.ics.forth.gr/isl/3M

[231] https://github.com/isl/Mapping-Memory-Manager

[232] http://n2t.net/ark:/99152/p0qhb66

learning based NLP	classifies named entities within English language text files; developed for the ADS Grey Literature Library, but may be adapted and implemented by other repositories for English language documents. ADS Named Entity Recognition Service API: available to generate metadata for external data management systems (i.e. to improve search & retrieval)		application: the code can be provided to other developers Online NER service API interface[233]
Rule-based NLP	OPTIMA for CIDOC-CRM semantic annotation of archaeological reports. OPTIMA (main parts based on the open source GATE platform [gate.ac.uk]: is a rule-based semantic annotation system that performs several NLP tasks	USW	Application/code[234]
NLP pipelines	Rule-based Named Entity Recognition pipelines for the text mining of English, Dutch and Swedish archaeological reports (run on the GATE platform)	USW	Application/code on GitHub[235]
Rule-based NLP	TextProcessMiner tool: uses verb semantics for mining documents for described methods and activities and a rule-based approach for detecting relationships between them (developed in Python employing existing NLP libraries such as Phython NLTK)	CSIC-Incipit	Research prototype, not yet available for general use (contact the developers: Epure *et al*. 2015)
Data aggregation and portal			
	MoRe (Metadata & Object Repository) aggregator: http://more.dcu.gr	ATHENA-DCU	MoRe is provided as a Cloud-based service
	The ARIADNE Portal is a web application based on the Laravel open source software. Its main purpose is to offer access to the ARIADNE Catalog data provided through Elasticsearch. The source code is hosted on GitHub together with installation instructions	ARIADNE	Application/code on GitHub[236]
Data repositories			
	Repository software of the Digital Collaboratory for Cultural Dendrochronology (DCCD): http://dendro.dans.knaw.nl	KNAW-DANS	Application/code on GitHub[237]
	DAI provides mirror hosting and back-up for the Open Context data publication platform (Digital Antiquity consortium, USA). DAI employs the platform for own data dissemination, and supports the expansion of its capabilities for data visualization and analysis	DAI	http://opencontext.dainst.org/
Visual content / 3D			
Visual Media Services	Web-based services that allow publication and visualisation of high-resolution images, reflectance transformation images (RTI), and high-resolution 3D models on the web. The services employ WebGL, SpiderGL and 3DHOP (3D Heritage On-Line Presenter),	CNR-ISTI	http://visual.ariadne-infrastructure.eu

[233] http://ads.ac.uk/nlp/demo.jsf

[234] https://sourceforge.net/projects/optimacidoc/?source=directory

[235] https://github.com/avlachid/Multilingual-NLP-for-Archaeological-Reports-Ariadne-Infrastructure

[236] https://github.com/dainst/ariadne-portal

[237] https://github.com/DANS-KNAW/dccd-webui

2D / high-resolution images	The service converts a high-resolution image into a multi-resolution format, enabling progressive transmission and visualization by means of a web-enabled image browser (included in the visual media services).	CNR-ISTI	http://visual.ariadne-infrastructure.eu
2D / RTI	Reflectance Transformation Imaging (RTI): Web-RTIViewer (included in the visual media services)	CNR-ISTI	http://vcg.isti.cnr.it/rti/webviewer.php
MeshLab	MeshLab is an open source, portable and extensible system for processing and editing of unstructured 3D triangular meshes. It provides tools to process unstructured models from 3D scanning data.	CNR-ISTI	http://meshlab.sourceforge.net
3DHOP	3DHOP (3D Heritage Online Presenter) for interactive presentation of high-resolution 3D models (included in the visual media services); the efficient visualization of 3DHOP is based on WebGL and a Javascript implementation of the Nexus multi-resolution framework	CNR-ISTI	http://3dhop.net/download.php
Landscapes Services	Landscape Services: web-based services that support generation and management of 2D/3D interactive WebGIS environments; web services include: Cloud services, 2D services, 3D terrain services, tools for visualization, interaction and editing, distributed composing services	CNR-ITABC	http://landscape.ariadne-infrastructure.eu

5.4.3 Sharing between academia and industry and potential for industrial innovation

ARIADNE is not an initiative of the "academia", rather the initiative has been promoted mainly by archaeological institutes, data archives and technology developers. Indeed the consortium of 23 organisations only includes four universities, and at two of them the project partner is a data archive[238]. Collaboration with other organisations based on cooperation agreements involves several universities alongside archaeological institutes, governmental heritage agencies, archaeology/ heritage museums and archives, and other institutions.

Nevertheless, the outcomes of ARIADNE are of course available to businesses and public sector organisations active in archaeology, heritage management, and related areas such as heritage-led regional development and tourism. While such businesses and organisations may benefit in some ways from ARIADNE services (e.g. access to relevant data), the notion of "industrial innovation" as promoted by the Research Infrastructures programme can hardly be applied to archaeology. Another question is if industrial actors may play a role in the provision of data infrastructure services for archaeological and other cultural heritage research and dissemination.

Potential benefits for archaeological businesses

The notion of industrial innovation through Research Infrastructures is informed by RIs in fields such as physics, energy, materials or life sciences research and development. In these fields innovation may result from advances in the construction/upgrades of a RI involving industrial providers of components (e.g. procurement of innovative instrumentation), joint R&D projects, or the use of

[238] University of York (Archaeology Data Service, UK), University of Gothenburg (Swedish National Data Service, Sweden), University of South Wales (UK) and Leiden University (NL)

experimental facilities by industrial researchers and developers (EIRIISS 2013). Studies on industrial innovation related to RIs typically centre on "big science" research facilities (Autio 2014; Technopolis Group 2013), among which the European Organisation for Nuclear Research (CERN) features as the most prominent example (OECD Global Science Forum 2014; Florio *et al*. 2015).

In contrast, industry in archaeology means contract archaeologists and consultants that are active in so called developer-led or preventive archaeology. Their businesses are mostly small, some very small (just one or two people) and some large ones. The larger businesses in the UK such as Oxford Archaeology and Wessex Archaeology (each with over 200 staff) are charitable trusts. The businesses provide fieldwork services for developers and heritage management agencies ranging from pre-development evaluation if archaeological deposits are present to rescue excavations in the course of development projects.

This industry has grown rapidly after the implementation in national regulations of the Council Directive (85/337/EEC) *Environmental Impact Assessment* (1985 and amendments)[239], and the Council of Europe's *European Convention on the Protection of the Archaeological Heritage* (1992)[240]. The Environmental Impact Assessment Directive established the requirement for the environmental impact of any significant land use change to be assessed, and for subsequent mitigation to take place where required (cultural heritage, including archaeological remains, was identified as an environmental component to be considered). The Council of Europe's Convention called for the integration of archaeology in the planning/development process.

In some European countries commercial contract archaeology has become the dominant form of field archaeology (e.g. in the Netherlands and the UK) while in others public bodies play a greater role. In France the Institut National des Recherches Archéologiques Préventives (Inrap) is the largest actor in preventive archaeology. Inrap and local authorities have a monopoly on pre-development evaluations while commercial companies are allowed to tender for excavations. Another example is that in some German *Länder* commercial firms are contracted and supervised by the state monument office, not directly by the developer (on the situation in different countries see Bozóki-Ernyey 2007; Willems 2007; Schlanger & Aitchison 2010; Bradley *et al*. 2012; Vander-Linden & Webley 2012).

The archaeological businesses will hardly benefit from the ARIADNE e-infrastructure initiative in similar ways as industrial providers of special instrumentation and services for large-scale physical Research Infrastructures. In this context innovation may result from industrial providers being challenged to come up with novel solutions, or take advantage of new knowledge and technologies developed in joint R&D projects with the RI providers and users.

In archaeology one area where both private sector and academic archaeologists can benefit is the sharing of the outcomes of their work through digital archives. Contract archaeologists produce many fieldwork reports which are of high relevance for progress in archaeological knowledge (cf. Bradley 2006; Ford 2010; Fulford & Holbrook 2011). If such reports can be made better accessible

[239] Environmental Impact Assessment, Council Directive of 27 June 1985 on the assessment of the effects of certain public and private projects on the environment (85/337/EEC); the Directive addresses "cultural heritage" in Article 3 and mentions "architectural and archaeological heritage" in the listing of aspects of the environment that may be significantly affected by a proposed development project (Annex IV). The EIA Directive of 1985 and its three amendments (1997, 2003, 2009) have been codified by the Directive 2011/92/EU (13 December 2011) and recently amended by the Directive 2014/52/EU (16 April 2014). European Commission: Environmental Impact Assessment, http://ec.europa.eu/environment/eia/eia-legalcontext.htm

[240] Council of Europe (1992): European Convention on the Protection of the Archaeological Heritage (Revised), Valetta, 16.I.1992, http://conventions.coe.int/Treaty/en/Treaties/Html/143.htm

together with academic research and synthesis, all actors can benefit from a common resource, e.g. for preparing fieldwork, excavations and conservation of work.

In the UK it has been estimated that much university teaching was up to ten 10 years out of date because results of contract archaeologists' fieldwork did not find their way into the academia (cf. Hardman & Richards 2003: 325)[241]. Since 2005 provisions are in place so that such fieldwork reports are deposited with the Archaeology Data Service (ADS)[242]. At present the ADS digital library contains about 40,000 reports and it is heavily used by archaeologists across the board. Another example is the E-depot for Dutch Archaeology (managed by DANS) which contains over 20,000 reports.

Access to more and richer data and information about archaeological sites, monuments and objects will also benefit heritage-led regional development projects, e.g. in areas such as urban regeneration and cultural heritage tourism (Sutherland & Tweed 2007; Cultural Heritage Counts for Europe 2015). Special ARIADNE services such as the Visual Media Services may also be used in the online presentation of archaeological and other cultural heritage objects and sites.

ICT industry involvement in data infrastructure services

There is also the question if ICT businesses may play a role in the provision of data infrastructure services for research and dissemination. The evaluation of the FP7 Research Infrastructure programme states: *"It is obvious that the impact on industry as user is limited due to the low participation numbers in the programme – both as participant and 'external' user of the RI. (…) low participation rates were especially the case for the Integrating Activities projects and the ESFRI projects (Preparatory Phase and Implementation). The case studies showed that in those projects development of technological tools such as software and middleware was entrusted to computing scientists rather than (private sector) engineers. It would be worth investigating whether this was justifiable because of the exploratory nature of the developments needed, whether it was due to a perceived lack of business case for the private sector, or whether the cause should be found in the social/cultural sphere (lack of contacts, mistrust, etc.)"* (EPIRIA 2014: 60).

ARIADNE followed the general pattern of Integrating Activities in that research organisations rather than businesses of the ICT sector have been entrusted with the development of the technical solutions and services. The main reason is that the involved research organisations and digital archives have a track record in implementing data services for the cultural heritage sector. Data infrastructure and services build on a well-established set of technical approaches and open standards and software so that ICT companies may try becoming service providers. However we assume that running a data infrastructure and services specifically for archaeological research and dissemination (or other fields of research) does not represent a business case for private sector companies.

The EPIRIA evaluation of the FP7 RI programme found that industry participation was somewhat higher in horizontal e-Infrastructure projects than in Integrating Activities. In such projects for Communication Networks, Computational Infrastructures, Data Infrastructures & Services (typically for large domains such as Energy, Earth & Environmental and Life Sciences), and Virtual Research Communities/Environments industry participants were predominantly telecommunication companies, middleware and other software suppliers (cf. EPIRIA 2014: 8-9 and 27). Obviously research organisations have been the drivers and coordinators also of these projects. The main area where commercial providers have initially taken the lead is the market of Cloud-based services. But it

[241] See also ARIADNE: Grey Literature Special Interest Group, http://www.ariadne-infrastructure.eu/Community/Special-Interest-Groups/Grey-Literature

[242] ADS: Library of Unpublished Fieldwork Reports, http://archaeologydataservice.ac.uk/archives/view/greylit/

is unlikely that such providers will play a major role in ventures like the European Open Science Cloud (EOSC)[243].

Concerning data archives the situation is roughly the same as with e-infrastructures. The area of data archives is very much about a division of work in the publishing sector. Most research publishers do not see data management and preservation as part of their core business, which is producing and marketing of publications. Rather they understand it as a responsibility of the authors, the authors' institutes or the research community as a whole (cf. PARSE.Insight 2009: 68-70). As open data mandates of research funders have become more widespread, most publishers recommend dedicated research data archives[244], while few have implemented an own repository for data underpinning publications in their journals (e.g. GigaScience's GigaDB repository[245]). Data repositories which are operated by commercial actors are rare: There is Figshare, which since 2012 is run by the Digital Science brand of Macmillan Publishers[246], and Mendeley (owned by Elsevier) in November 2015 launched Mendeley Data[247], for which DANS provides long-term data archiving (DANS-KNAW 2015; Hoey 2015).

5.4.4 Summary of results

Sharing of knowledge and technologies across fields of research

ARIADNE has shared new knowledge and results of technological development widely across relevant related fields of research. The knowledge and technology transfer includes sharing of models, tools/ techniques and services, presentations, tutorials and short courses for tool/service users, good practice guides, and publications on use cases and research results.

Know-how and technologies for data archiving and publication

In many events and other dissemination activities ARIADNE has put the need for data sharing through state-of-the-art archives and integrating e-infrastructure on the agenda of the research community. Project partners have shared widely good practices in the development and operation of digital archives. In particular, ARIADNE has fostered knowledge transfer between established data archives/centres and initiatives for centres in other European countries, so that new entries may "leapfrog" to a state-of-the-art solution by learning from acknowledged benchmarks. In addition to this knowledge transfer ARIADNE partners have contributed to the development and sharing of data archiving and publication solutions. Partners have trialled and provided feedback on the open source ARCHES platform for cultural heritage inventory and management developed jointly by the Getty Conservation Institute and the World Monuments Fund. DAI provides mirror hosting and back-up for the Open Context data publication platform (Digital Antiquity consortium, USA), employs the platform for own data dissemination, and supports the expansion of its capabilities for data visualization and analysis. DANS makes the repository software of the Digital Collaboratory for Cultural Dendrochronology (DCCD) available open source to promote sharing and integration of dendrochronological data.

[243] European Commission, Research & Innovation: European Open Science Cloud, http://ec.europa.eu/research/openscience/index.cfm?pg=open-science-cloud

[244] For example see the list of repositories recommended by Nature's Scientific Data journal, http://www.nature.com/sdata/policies/repositories

[245] GigaDB repository, http://gigadb.org/site/about

[246] Figshare, http://figshare.com

[247] Mendeley Data, https://data.mendeley.com

Know-how and technologies for integrating e-infrastructure and services

Data infrastructures and services employ various standards and technologies, some of which have been adapted and/or improved by the project. ARIADNE provides an example for the adaptation and use of the W3C recommended Data Catalog Vocabulary – DCAT for the description of datasets of a domain of research; employs the MoRe (Metadata & Object Repository) aggregator which is provided by ARIADNE partner Athena-DCU as a Cloud-based service; and shares tools which enhance data interoperability, e.g. the interactive Vocabulary Mapping/Matching Tool and the Mapping Memory Manager (3M) which facilitates the mapping of databases to the extended CIDOC-CRM.

Natural Language Processing (NLP)

NLP is a well-established field of research and development with numerous solutions and productive applications. ARIADNE work in this field employed different frameworks such as GATE (General Architecture for Text Engineering) and Python NLTK (Natural Language Toolkit), and investigated various methods for improving NLP tasks specifically for archaeology and cultural heritage content. A major goal in this area has been making reports of archaeological fieldwork, specialist analysis and other "grey literature" better accessible and useful through NLP based metadata extraction. Arguably the greatest advance has been achieved in the investigation of what can be achieved by, and what still needs to be improved for, employing archaeological terminologies in different languages for this purpose.

Visual Media and Landscape Services

Project partners have developed web-based services for visual media (high-resolution images, Reflectance Transformation Imaging and 3D artefact models) and large 3D terrain and landscape models. These services are included in the ARIADNE portfolio of web-based services. Employing such services/tools in research projects, for content deposited in digital archives and/or published in e-journals greatly advances researchers' capability to publish, access, visualize and study archaeological and other cultural heritage objects online.

ARIADNE's focus has been on specific needs and requirements of archaeology and cultural heritage. Therefore most of the models, tools/techniques and services have been specifically developed or customised for users of this sector, but some may also be relevant to other domains.

Sharing between academia and industry and potential for industrial innovation

The outcomes of ARIADNE are also available for businesses and public sector organisations active in archaeology, heritage management and related areas.

Industrial innovation in archaeology

With regard to businesses in these fields the notion of "industrial innovation" as promoted by the Research Infrastructures programme can hardly be applied. The notion is informed by large physical research infrastructures where innovation may result from industrial providers being challenged to come up with novel instrumentation, joint R&D projects with the RI, or the use of experimental facilities. Industry in archaeology means contract archaeologists and consultants who provide fieldwork services in so called developer-led or preventive archaeology.

One area where both private sector and academic archaeologists can benefit is the sharing of the outcomes of their work through digital archives. Contract archaeologists produce many fieldwork reports that are important for progress in archaeological knowledge. If such reports can be made better accessible together with academic research and synthesis, all actors can benefit from a common resource, e.g. for preparing fieldwork, excavations and conservation of work.

Access to more and richer data and information about archaeological sites, monuments and objects can also benefit heritage-led regional development projects, e.g. in areas such as urban regeneration and cultural heritage tourism. Special ARIADNE services such as the Visual Media Services may be used in the online presentation of archaeological and other cultural heritage objects and sites.

Industry involvement in data infrastructure services

With regard to the participation of industrial actors in the development of e-infrastructures the EPIRIA evaluation of the FP7 Research Infrastructure programme has shown that their involvement in Integrating Activities has been rather low. ARIADNE followed the general pattern of Integrating Activities in that research organisations rather than ICT businesses have been entrusted with the development of the technical solutions and services. The main reason is that the involved research organisations and digital archives have a track record in implementing data services for the cultural heritage sector. Data infrastructure and services build on a well-established set of technical approaches and open standards and software so that ICT businesses may try becoming service providers. However we assume that running a data infrastructure and services specifically for archaeological research and dissemination (or other fields of research) does not represent a business case for private sector companies.

Data archives present a similar situation based on a division of work in the academic publishing sector. Most research publishers do not see data management and preservation as part of their core business. As open data mandates of research funders have become more widespread, most publishers recommend dedicated research data archives, while few have implemented an own repository for data underpinning publications in their journals. Data repositories which are operated by commercial actors are rare: Examples are Figshare (run by Macmillan Publishers' Digital Science) and Mendeley Data (Elsevier), for the latter DANS provides long-term data archiving.

6 Annex A: Impact indicators applied in the evaluation

6.1 Indicators defined in ARIADNE's Description of Work

The table below gives an overview of the ARIADNE impact indicators defined in the project's Description of Work (Part B, section 3, pp. 55-56).

Objective	*Intended impact*	*Action*	*Impact indicator level achieved at year 4*
Innovation and community building	Foster the innovation potential of RIs based on close cooperation with institutions and end-users	Early and active involvement of institutional stakeholders	○ Involvement and active participation by the major institutional stakeholders from all EU Members States, comprising the leading: Antiquity authorities and other public authorities, Archaeological research centres, and Research and professional associations. ○ Liaisons with relevant research institutions and initiatives outside Europe.
		Early and active involvement of end-users	○ At least 400 end-users from the above and other institutions participating in project activities (e.g. special interest groups, conference sessions, etc.).
		Strong innovation impact focus and strategies	○ Innovation Agenda and Action Plan endorsed, published and put into practice by the members of the consortium and affiliated institutions. ○ Business Model evaluated by external experts and supported by the members of the consortium and affiliated institutions.
Dissemination and training	Promote awareness and good practices, develop "next generation" skills	Effective dissemination channels	○ Audience of 3000 reached with information material (folders, project announcements, etc.). ○ Project website consulted by at least 12,000 visitors.
		Good practice guides	○ 1500 copies of Good Practice guides distributed or downloaded from the project website.
		Training offering	○ 250 users trained in tutorials at events or short training courses on effective RI use, the majority young (*) researchers. (*) A "young" researcher is a graduate student, a PhD candidate, or a Post-Doc level researcher.
RI access and usage	Widen the use of RIs and ICT-supported archaeological research	Transnational access (TNA) to RIs	○ 300 researchers requested transnational access to RIs, the majority of which young researchers. ○ High benefit of the RI access for their projects confirmed by the visiting researchers.

		Provision of TNA on-line services	○ 800 different anonymous users availing of on-line infrastructure services during last year. ○ 300 registered users of the on-line infrastructure services, the majority young researchers
Critical mass of content	Increase the volume and richness of accessible data	Inclusion of, and provision of access to, rich and large volumes of data	○ At least 5.000.000 archaeological records available for access, covering at least 70% of European countries. ○ Rich information provided in terms of metadata and content, i.e. not only text records but endowed with images, 3D etc. ○ 100.000 reports available for searching and browsing.
Overcome fragmentation	Leverage the usefulness of datasets and services	Enhancement and integration of datasets	○ 100% of datasets integrated via mappings & crosswalks, or other appropriate integrating technologies such as GIS, Linked Data, etc., according to dataset typology.
		Increase the use of integrated on-line services	○ 30% increase in services provided (compared to currently available ones).
		Deployment of integrating technologies	○ 25% of datasets linked as Open Linked Data. ○ 100% of all datasets with a spatial component integrated in a common GIS platform.
Unified access	Ensure usability and usefulness	Provide unified access interface	○ 100% of datasets accessible through a common interface.
		Provide innovative tools	○ 100% of datasets availing of innovative visualization and semantic annotation tools (where applicable according to dataset type).
Long-term preservation	Ensure long-term perpetual access to datasets	Implement data maintenance and curation processes	○ Long-term preservation process activated for all datasets.
Innovation in archaeological research practices	Development of novel ICT-supported research methods (e-archaeology)	Provide and pilot extended data reference models, data linking and processing capability	○ Conceptual Reference Model extended to cover new domains as relevant to archaeological research (e.g. monuments and standing structures, excavation data and scientific laboratory analysis). ○ Open Linked Data annotation and integration methods established and demonstrated for archaeological cases. ○ Data mining and natural language techniques established and demonstrated. ○ Archaeological e-research frameworks established. ○ At least 10 pilot projects completed demonstrating an innovative approach using ARIADNE's tools.

6.2 Expected broader impacts defined in the Work Programme

In addition to the ARIADNE impact indicators (above) the evaluation took account of a number of broader impacts the FP7 Work Programme for Research Infrastructures (2012) expects from Integrating Activities[248]. In order to address the expected impacts these have been extracted from the text in the Work Programme, organised and indicators elaborated for the impact evaluation. Below we reproduce the text of the Work Programme and present the table of the elaborated Programme impact indicators.

RI programme – Expected impacts of Integrating Activities

"Expected impacts: Integrating Activities are expected to have a structuring impact on the ERA and on the way research infrastructures operate, evolve and interact with similar facilities and with their users. Operators of infrastructures will develop synergies and complementary capabilities in such a way as to offer an improved access to researchers and to develop their innovation potential. Likewise, a more co-ordinated approach between infrastructure operators, users and public authorities will enable to optimise the development, use and sustainable operation of the identified research infrastructures. In addition, a closer interaction between a large number of researchers active in and around a number of infrastructures will facilitate cross-disciplinary fertilisations and a wider sharing of knowledge and technologies across fields and between academia and industry. Integrating Activities should also contribute to increase the potential for innovation of the related research infrastructures, in particular by reinforcing the partnership with industry, through e.g. transfer of knowledge and other dissemination activities, activities to foster the use of research infrastructures by industrial researchers, involvement of industrial associations in consortia or in advisory bodies. The focus on innovation should be reflected in the description of the objectives of the proposed actions."

Elaborated programme impact indicators

Impact areas	***Overall goal / impact action***	***Impact indicators***
Structuring impact on the European Research Area	Promote cooperation and connect research communities and resources (data, ICT services) at the European level	○ European-level e-infrastructure for the field of archaeology, enabling cross-country data sharing, integration and access ○ Involvement of a large community of stakeholders in the e-infrastructure and other project activities ○ High-level recognition and support of the initiative
Coordinated evolution of Research Infrastructures, incl.	Contribute to the coordinated development/evolution, synergies	○ Knowledge exchange and coordination with other e-infrastructure initiatives in the field of humanities and heritage sciences

[248] FP7 Work Programme 2012. Capacities: Part 1: Research Infrastructures. European Commission C(2011)5023, 19 July 2011, page 9, https://ec.europa.eu/research/infrastructures/pdf/wp2012_research_infrastructures.pdf

e-infrastructures	and integration of e-infrastructures in the target area	○ Collaboration with other initiatives to enable data integration and e-infrastructure based research in the multi-disciplinary field of archaeology
Improved development, access/use and sustainable operation of RIs	Support optimal development, operation and use of integrated data archives, ensuring that researchers and other users have reliable and efficient access to data they require for research and other purposes	○ Integrated access to archaeological data archives enabling use of data from different European countries ○ Identification of the requirements for and sharing of best practices in the sustainable operation of data archives ○ Promotion of new data centres and knowledge transfer from established centres
Cross-disciplinary fertilisation	Enable fertilisation between different fields of research, e.g. sharing of data, conceptual understanding and integration, collaboration on new tools/services	○ Data services relevant to all domains of the multi-disciplinary field of archaeological research ○ Fostering cross-disciplinary fertilisation among researchers of different domains (e.g. data sharing and integration, collaboration of scholars and technologists for new tools/services)
Sharing of knowledge and technologies and potential industrial innovation	Share new knowledge and technical solutions (tools / services) across fields of research, with related public sector bodies and businesses, and enable innovation beyond the research sector	○ Sharing of new knowledge (models, methods) and advanced or new tools and services across fields of research ○ Project outcomes also available for public sector organisations and businesses ○ Potential for innovation of businesses active in archaeology and cultural heritage

7 Annex B: Background study for a comparative approach

The ARIADNE impact evaluation aimed to align the work with an existing evaluation framework in order to possibly compare the results of ARIADNE with similar other projects. We looked into various available frameworks and studies but found that most are not or only partially relevant for the purpose. One generic framework for all types of e-infrastructures that appeared as useful is described in greater detail and applied to ARIADNE outcomes.

7.1 The quest for a comparative approach to e-RI impacts evaluation

In the last about 10 years a number of projects funded by the European Commission and national funding bodies developed conceptual frameworks for the evaluation of the impact of different types of research infrastructures (RIs). Frameworks for large-scale single-sited RIs, projects on the ESFRI Roadmap and different types of e-infrastructures have been developed, using ex-ante (e.g. foresight) and/or ex-post study methods (e.g. surveys, self-evaluation tools). The empirical work conducted in several framework studies found that RI projects are often unfamiliar with impact assessment methods and identified issues that impede a comparative approach, e.g. the complex landscape of RIs, lack of common impact targets and benchmarks (Manieri & Nardi 2012).

The ARIADNE impact evaluation aimed to align the work with an existing evaluation framework in order to possibly compare the results of ARIADNE with similar other projects. ARIADNE is an Integrating Activity hence the first choice would have been an evaluation framework for such projects. However we found that such a framework does not exist, despite the fact that across all disciplines about 90 such projects have been funded under the 7th Framework Programme[249]. It appeared that, in general, Integrating Activities should be evaluated according to their scope and expected impacts as defined in the Description of Work (Grant Agreement). The reason arguably is that the significant differences of the projects with regard to disciplines, types of research infrastructures and user communities do not allow the use of a common evaluation framework.

Nevertheless the evaluation looked for another suitable framework which might be employed for comparison. A major goal of ARIADNE is to establish an e-infrastructure for the domain of archaeology, more specifically a data infrastructure and services. In the study it became clear that due to the differences between the various types of e-infrastructures only a framework for data infrastructures and services or a generic framework for all types of e-infrastructures might be applied.

The sections below present the results of the study work. The first section gives an overview of frameworks and studies that are not or only partially relevant for the ARIADNE impact evaluation. Finally, one generic framework for all types of e-infrastructures is presented and applied to ARIADNE outcomes.

7.2 Frameworks not or only partially relevant to ARIADNE

This section gives an overview of various Research Infrastructure (RI) evaluation frameworks and studies which are not or only partially relevant to ARIADNE. The overview covers “big science” research facilities (mainly single-sited RIs); ESFRI Roadmap projects; E-infrastructure for large RIs (incl. ESFRI projects); and different types of e-infrastructures – National Research and Education

[249] European Commission, DG Research & Innovation, Infrastructures: FP7 funded I3 projects (Networks of RIs funded as Integrating Activity projects), https://ec.europa.eu/research/infrastructures/index_en.cfm?pg=ri_projects_fp7

Networks, Grid infrastructure, High-Performance Computing and others facilities. Furthermore included are the evaluations of the Research Infrastructure activity in FP6 and FP7.

"Big science" research facilities, mainly single-sited RIs

A vision for strengthening world-class research infrastructures in the ERA *(Expert Group on Research Infrastructures 2010):* One chapter of this report addresses the need for evaluation and impact assessment of RIs and provides a table of several impact dimensions and examples.

RIFI - Research Infrastructures: Foresight and Impact *(FP7, 2009-2011):* Explored how various foresight and other methods can be used for the assessment of socio-economic impacts of future RI projects on hosting regions and communities. The project produced an extensive methodological framework and an online tool. The FenRIAM - Foresight Enriched Research Infrastructure Assessment Methodology centres on the potential impact of single-sited RIs. Websites: http://rifi.gateway.bg and http://www.fenriam.eu

EIRIISS – European Industrial and RI Interaction and Support Study *(FP7, 2011-2012)*: Analysed the challenges for industry to engage with RIs that provide scientific instrumentation. The final report of the project is available at: http://cordis.europa.eu/project/rcn/100413_en.html. An interim report on the role of RIs in innovation by the ESFRI Working Group on Innovation (May 2015) stressed *"the concept of 'industry as a full partner of RIs' (supplier and user) as a way forward to promote extensive partnerships on joint R&D projects and cooperative programmes, development of advanced technologies, innovation, and training. RIs and industry can generate active ecosystems of innovation exploiting their complementary enabling technologies and support services"* (ESFRI 2016: 27).

Big Science and Innovation *(Technopolis Group 2013):* The report presents the findings of an explorative study of the relationship between large research facilities and innovation (with a focus on UK facilities). It provides advice about approaches to the evaluation of innovation outcomes alongside a bibliography of past evaluations.

Innovation from Big Science: Enhancing Big Science Impact Agenda *(Autio 2014):* Provides a review of the literature on impact generation of big-science facilities and looks at seven projects funded by the UK Large Facilities Capital Fund (LFCF), e.g. Diamond Synchrotron, Halley VI Antarctic Research Station and, as a case of e-infrastructure, the High End Computing Terascale Resource (HECToR).

The Impacts of Large Research Infrastructures on Economic Innovation and on Society: Case Studies at CERN *(OECD Global Science Forum 2014):* The report addresses the potential economic and societal impacts of international research facilities, using case studies from one of the largest facilities: the European Organisation for Nuclear Research (CERN). See also Le Goff (2011) and Florio *et al*. (2015).

Evaluating and Monitoring the Socio-Economic Impact of Investment in Research Infrastructures *(Technopolis Group 2015):* A guide for evaluating and monitoring the socio-economic benefits of investment in large, mainly single-site research infrastructures for different stakeholders. The guide is based on a review of the literature, a schematic impact assessment framework, and experience from evaluating RIs projects.

Exploring Cost-Benefit Analysis of Research, Development and Innovation Infrastructures: An Evaluation Framework *(Florio et al. 2016):* The report presents the results and lessons learned on how to apply ex-ante cost-benefit analysis for major research, development and innovation infrastructures. The research has been carried out by a team of economists and scientists at the University of Milan (Departments of Economics, Management and Quantitative Methods and Physics) and the independent Centre for Industrial Studies (CSIL) during a three-year project supported by the European Investment Bank Institute (http://www.eiburs.unimi.it). Their model breaks down benefits into two broad classes: (i) use benefits by different categories of infrastructure users such as scientists, firms, students and general public visitors, and (ii) non-use benefits

concerning the social value of the discovery potential of the RDI infrastructure regardless of its actual or future use. The model has been applied to two cases in physics, the Large Hadron Collider at CERN (Florio *et al*. 2015) and the National Centre for Oncological Treatment (CNAO) in Italy (Pancotti *et al*. 2015).

Cost-Benefit Analysis of the Large Hadron Collider to 2025 and beyond *(Florio et al. 2015)*: The authors designed an empirically testable cost-benefit analysis model and applied it to the Large Hadron Collider (LHC) at CERN. They suggest that the evaluation of benefits can be based on determining their value to users (scientists, early-stage researchers, firms, visitors) and non-users (the general public). Four classes of contributions to users are identified: knowledge output, human capital development, technological spill-overs, and cultural effects (e.g. general public CERN exhibitions or website and social media channels). Benefits for non-users can be evaluated, in analogy to public goods with no practical use (such as environment preservation), using willingness to pay. The authors calculated the probability distribution of cost and benefits for the LHC since 1993 until planned decommissioning in 2025, and found a 92% probability that benefits exceed its costs, with an expected net present value of about 3 billion euro, not including the unpredictable economic value of discovery of any new physics. The authors argue that the proposed evaluation approach can be replicated for any large-scale research infrastructure. The evaluation could help decision-making on competing projects with a socio-economic appraisal complementary to other evaluation criteria.

Project Preparation and Cost-Benefit Analysis of RDI Infrastructure projects *(JASPERS 2013):* A methodological guidance paper of the Knowledge Economy and Energy Division of JASPERS - Joint Assistance to Support Projects in European Regions for the development of the feasibility study and cost-benefit analysis for Research, Development and Innovation infrastructure projects. The paper focuses on research infrastructure, higher education infrastructure and science parks projects.

Guide to Research and Innovation Strategies for Smart Specialisations - RIS 3 (Smart Specialisation Platform 2012): Smart specialisation is a concept promoted by the European Commission which suggests that regions should concentrate resources on a few key priorities rather than spreading investment thinly across development areas and business sectors. It is understood that this can ensure more effective use of public funds as well as stimulate private investment, i.e. public-private partnerships (cf. European Commission 2010: 6). The RIS3 Guide features research infrastructures, centres of competence and science parks under the "delivery instruments and horizontal approaches" (Smart Specialisation Platform 2012: 74-77). The list of RIS3 instruments and approaches also includes, for example: Innovation friendly business environments for SMEs, Financial engineering instruments, Innovative public procurement, Universities, Cultural and creative industries, Social innovation, Green Growth, Internationalisation. Six key enabling technologies for Europe are considered: micro-/nano-electronics, photonics, nanotechnology, industrial bio-technology, advanced materials and advanced manufacturing systems.

ESFRI Roadmap projects

Indicators of pan-European Relevance of Research Infrastructures *(Expert Group on ESFRI Indicators 2013a/b):* The implementation of the ESFRI Roadmap projects for the construction (or major upgrade) of research facilities of pan-European interest has led to increased attention to studies measuring the scientific, social and economic benefits deriving from these infrastructures. The Expert Group on ESFRI Indicators suggested a number of indicators for the ex-ante and ex-post evaluation of research infrastructures of pan-European interest. Among the ESRFI Roadmap projects since 2006 the only dedicated e-infrastructure project is PRACE - Partnership for Advanced Computing in Europe, a distributed RI, which has been implemented. Of the other 34 distributed RIs many have e-infrastructure components (e.g. CLARIN - Common Language Resources and Technology Initiative).

EVARIO - Evaluation of Research Infrastructures in Open innovation and research systems *(FP7, 2011-2012):* Developed an evaluation framework and method focused on "learning impacts around RIs". The framework centres on individual actors (RI operator, suppliers, users) and learning effects on capacity, performance, and direct (internal) and indirect (external) value creation. The framework is extensive but not e-infrastructure specific. It has been applied to biological & medical sciences RIs on the ESFRI Roadmap based on case studies and figures such as biological reference materials produced, patent applications, publications, PhD thesis, etc. Website: http://evario.u-strasbg.fr

E-infrastructure for large RIs, incl. ESFRI projects

Survey of e-infrastructure needs for eight large infrastructures *(Swedish Research Council 2015):* The survey has been conducted by the Swedish National Infrastructure for Computing (SNIC) and provides a detailed account of the e-infrastructure needs of large RIs of different natural and life sciences disciplines: MAX IV Laboratory, XFEL - The European X-ray Free Electron Laser, Worldwide LHC Computing Grid (WLCG), EISCAT_3D - The Next Generation European Incoherent Scatter Radar System, Onsala Space Observatory, Bioinformatics Infrastructure for Life Sciences (BILS), National Genomics Infrastructure (NGI), Swedish Bioimaging. EISCAT_3D and XFEL are ESFRI projects, BILS is the Swedish node of ELIXIR and the Onsala Space Observatory takes part in SKA - Square Kilometre Array (both ELIXIR and SKA are ESFRI projects).

Best Practices for the use of e-Infrastructures by large-scale research infrastructures *(e-IRG 2015):* The "guidelines document" of the e-Infrastructures Reflection Group was meant to support proposals to the ESFRI call for the 2016 roadmap with regard to the section 4 "e-needs" in "Part B: scientific impact, pan European relevance, socioeconomic impact & e-needs" of the online submission form for proposals. The section listed questions relevant to the specification of the e-Infrastructure requirements of the proposed ESFRI research infrastructure. The best practices suggested are summarised as follows: *"Check existing e-Infrastructures and related services for their use before defining the ICT infrastructure for your Research Infrastructure; Check with existing RIs how they realised their ICT infrastructure; Contact existing e-Infrastructures and ESFRI projects at national level and/or European level as appropriate; Work to an ICT synergy with other projects to encourage the development of the e-Infrastructure commons; Pay attention to the interoperability of services and data; Plan your access to ICT resources"* (ibid., 5-6). With regard to e-infrastructures the document mainly addresses GÉANT, PRACE, EGI.eu, Helix Nebula, EUDAT, OpenAIRE and Zenodo.

National Research and Education Networks

EARNEST - Education and Research Networking Evolution Study *(2006-2008):* The foresight study was funded by the GÉANT2 initiative and looked into the development of the networks in Europe over the next 5-10 years. The study addressed technical, economic and organisational issues of the networks and included a large user survey (about 4,400 researchers). Most respondents perceived benefits with regard to easier access to publications and other information via digital libraries and repositories, while the study found that the networks and content provider communities "are often two separate worlds". The main suggestion of the foresight study was a change from providing connectivity to providing network-related services for the connected institutions and end-users (EARNEST 2008).

ASPIRE Foresight Study *(2011-2012):* An update of the work conducted in EARNEST aimed at preparing the ground for planning the further development path of the networking infrastructure and services after completion of the GÉANT3 Project, at the local, national, European, and intercontinental levels (TERENA 2012).

Networking, Grid and High-Performance Computing

e·nventory - The European e-Infrastructures Observatory *(FP7, 2010-2012):* Developed a platform for monitoring investments, development, usage and impacts of networking, grid and high-performance computing e-infrastructures. The platform employs a set of 45 benchmarking indicators collected from institutions and projects such as the International Telecommunication Union (ITU), European Grid Initiative (EGI.eu), Trans-European Research and Education Networking Association (TERENA) and others. The impact indicators and visualizations are not focused on individual projects but concern the national level. The latest figures are for the year 2011. Website: http://www.enventory.eu

OSIRIS - Towards an Open and Sustainable ICT Research Infrastructure Strategy *(FP7, 2010-2012):* Aimed to support decision makings on future large scale investments in transnational ICT-based research infrastructures with useful models and information. Target areas of the project have been networks, grids, high-performance computing, and future internet projects. Website: http://www.ictresearchinfrastructures.eu

E-FISCAL - Financial Study for Sustainable Computing E-Infrastructures *(FP7, 2011-2013):* Analysed operational cost categories of grid and high-performance computing e-infrastructures participating in EGI and PRACE and compared them with similar commercially leased or on-demand offerings. Website: http://efiscal.eu

Various e-infrastructures

ERINA - Recommendations for Exploiting Research Infrastructure potential in Key Areas of the Information Society *(FP7, 2007-2008):* Explored the potential of e-infrastructures in the fields of e-health, e-government and e-learning. The study faced difficulties to acquire data for the intended methodology and finally had to do with a few case studies (ERINA 2008).

ERINA+ Socio-Economic Impact Assessment for e-Infrastructures Research Projects *(FP7, 2010-2012):* built on the ERINA Study and developed a framework aimed at measuring socio-economic impacts of EU-funded e-Infrastructure projects. ERINA+ offered ongoing projects a web-based self-assessment tool and support in the application of the tool. Unfortunately the project websites (http://www.erinaplus.eu, http://Platform.erinaplus.eu) have become inaccessible and project reports could also not be retrieved elsewhere on the Web; available are presentations by the project coordinator (Manieri 2012 and 2013).

Spatial data infrastructures (SDI), including INSPIRE*:* SDIs have received much attention by impact framework developers (e.g. Craglia & Johnston 2004; Craglia *et al*. 2008; Crompvoets *et al*. 2008; Steudler *et al*. 2008; Castelein & Manso-Callejo 2010). For the monitoring of the implementation of INSPIRE, the Infrastructure for Spatial Information in the European Community, there is a set of indicators established by a European Commission decision (2009/442/EC). The set includes 8 indicators which are monitored regularly: Existence of Metadata (%), Conformity of Metadata (%), Geographical coverage of spatial data sets (%), Conformity of spatial data sets (%), Accessibility of metadata through discovery services (%), Accessibility of spatial data sets through view and download services (%), Use of network services, and Conformity of network services (%). Furthermore there are 5 areas of implementation and use on which each Member State has to report 3-yearly: Coordination and quality assurance; Contribution to the functioning and coordination of the infrastructure (involvement of stakeholders); Use of the infrastructure for spatial information incl. use cases; Data sharing arrangements, and Cost and benefit aspects. See also: Mid-term evaluation report on INSPIRE implementation (European Environment Agency 2014).

SEQUOIA - Socio-Economic Impact Assessment for Research Projects *(FP7, 2010-2012):* Focused on the assessment of the socio-economic impact of research projects in the area of Software as a Service and Internet of Services. It aimed to develop a self-assessment methodology for projects in these fields of research and development. Project results are reported in: Passani *et al*. (2012).

IMPACT - Development of Impact Measures for e-Infrastructures *(Fraunhofer ISI & ZEW 2012):* Aimed to provide the European Commission with a conceptual framework for monitoring the impacts of all types of research e-infrastructure projects funded under the e-Infrastructures programme. The proposed indicators are intended to evaluate at the aggregate level their contribution to EU policy goals (Digital Agenda, Innovation Union), the European Research Area (ERA) science and innovation system, and other areas (Fraunhofer ISI & ZEW 2012). While developed for all types of e-infrastructures, most of the general indicators (suggested for all infrastructures) and specific indicators for data infrastructures together could be applied for a comparison between the outcomes of data infrastructure projects. Therefore, as a test case, we have applied the relevant IMPACT indicators to outcomes of the ARIADNE project (see *Section 7.3*).

Evaluation of the Research Infrastructure activity in FP6 and FP7

Community Support for Research Infrastructures in the Sixth Framework Programme: Evaluation of pertinence and impact *(European Commission 2009)*

The evaluation has been carried out by Rambøll Management and Matrix-Eureval between July 2007 and March 2009. The study gathered a wide range of evidence of the impact of EU support on RI development, scientific communities and research policy; also impacts on industry/economy and wider society were considered. The evaluation used a mix of methods for the collection and analysis of evidence, e.g. 30 structured case studies involving 176 interviews and statistical analysis from the case study sample and project survey data. The study covered 83 RIs, including 13 e-Infrastructure projects, 11 based on the I3 model and 2 coordination actions. The e-Infrastructures had a focus on high-speed networks (e.g. Research and Education Networks) and Grids for distributed computing.

The study provided solid evidence for several impact factors except industrial, economic and wider societal impacts which were not explicit in the programme objectives; also there was little evidence of projects having produced outcomes which might be commercialised (cf. pages 29-31). E-infrastructure projects achieved better results than other RI project in most types of impacts; this includes:

- Expansion of services by partner organisations and increase in the quality of RI services,
- Increase in the remote use of RI: evidence only for 18 projects, most of which e-infrastructures,
- Growth in the number of integrated datasets: in 40% of all projects, mostly evidenced for e-infrastructures,
- Increase in the degree to which researchers are networked as a result of the project,
- Increase in the number of non-European users of the RI,
- Increase in the industry use of the RI: only 16 projects considered industrial and economic impacts at the start of the project, mostly initiatives for new RIs (which may generate new business for suppliers) and e-infrastructure projects,
- Impact on wider society: only 16 projects considered such impacts at the start of the project and e-infrastructure projects (e.g. Research and Education Networks) were most likely to achieve liaisons with local communities and non-commercial use of research resources,
- More priority given to RIs in national research policies as a result of the project.

Increase in the quality of research data (e.g. standards and protocols) was highly relevant for all projects, most prominently within I3 based project and domains such as physics, energy, material sciences and analytical facilities. Increase in the number of people receiving training in the use of equipment was equally important for e-infrastructure and other RI projects, although enhanced access was more likely as a result of better IT quality.

The perceived greater impact of e-infrastructure projects on national research policies needs some explanation: E-infrastructure projects were generally shorter in duration and achieved impacts faster. But CSAs and Design Studies for new RIs were more likely to achieve impact, because CSAs promoted a coordinated approach to RI development, and Design Studies according to the ESFRI scheme required national commitment to proceed to the RI preparatory phase.

The study also recommended that a set of objective impact measures are developed for which comparable data can be collected *"moving away from opinion-based indicators"*; furthermore *"that evidence is collected which is in part differentiated between the e-infrastructure and the RI projects, in order to understand better the specificities of each area of the programme"* (European Commission 2009: 37). It can be assumed that the study paved the way to the subsequent funding of many impact evaluation frameworks in the Research Infrastructure activity of the 7th Framework Programme (i.e. E-nventory, ERINA+, IMPACT, RIFI and others).

As noted above the FP6 RI Programme did not emphasise objectives such as industrial, socio-economic and other regional impacts. This changed dramatically in the FP7 RI Programme with regard to both ESFRI and other infrastructure projects, including e-infrastructures.

EPIRIA - Evaluation of pertinence and impact of the EU research infrastructure activity in FP7 *(EPIRIA 2014)*

The evaluation of the EU FP7 Research Infrastructures activity has been carried out by Technopolis and Empirica between January 2013 and August 2014. In its quantitative analyses the study covers contracts signed under the FP7 RI programme before the end of 2012, a total of 313 projects, about half of which had finished at the time of the study. The evaluation provides a detailed structural analysis of the FP7 RI activity, including some comparison to FP6, and rich background information and exemplary cases.

The largest part of the study report covers the whole range of expected impacts, i.e. on the European RI landscape and internationalisation of RIs, EU and national policy making, research communities, industrial innovation and socio-economic impacts. Also the European added value of the RI Programme and sustainability of the programme results are addressed.

The impact chapter provides a rich description of impacts, including results of a questionnaire survey with respondents from 50% of the RI projects in the covered period. Unfortunately the study offers little in the way of a comparative analysis of impacts of RIs of different thematic areas, between e-infrastructures and other RIs, or between e-infrastructure projects. Interestingly the study builds on none the e-infrastructure impact frameworks addressed above; only the IMPACT study report is included in the bibliography.

Some comparative figures are given for the trans-national access to (physical) research infrastructures, a bibliometric analysis of publication patterns of different areas, and opinions about the funding of RI projects (based on the questionnaire survey). With regard to the latter the study authors emphasise that the RI policy does not meet the specificity of the social sciences and humanities (SSH) and that too little funding of RIs in this area will make it difficult to sustain, least extend and enhance their services; *"RIs in the Humanities and Social Science are underfinanced, both on the national and European level. In order to foster the competitive position of European research in the SSH domain, a substantial effort on the funding side should be undertaken"* (EPIRIA 2014: 78).

7.3 The IMPACT indicators for comparison of data infrastructures

We assume that due to the differences between the various types of e-infrastructures only a framework specifically for research data infrastructures or a generic framework for all types of research e-infrastructures could be applied for a comparison of ARIADNE's outcomes with those of similar initiatives. An evaluation framework for data infrastructures and services is not available. Therefore we consider the indicators suggested by the IMPACT project (Fraunhofer ISI & ZEW 2012) as the best choice for comparison.

IMPACT aimed to provide the European Commission with a conceptual framework for monitoring the impacts of all types of research e-infrastructure projects funded under the e-Infrastructures programme. This indicators-based monitoring would be conducted at the aggregate level and evaluate the combined contribution of the projects to EU policy goals (Digital Agenda, Innovation Union), the European Research Area (ERA) science and innovation system, and other areas.

While IMPACT developed a framework for all types of e-infrastructures, most of the general indicators (suggested for all infrastructures) and specific indicators for data infrastructures together could be applied for a comparison between the outcomes of data infrastructure projects. Below we present the indicators and apply relevant indicators to outcomes of the ARIADNE project. Other data infrastructure projects may compare their outcomes to ARIADNE's results for these indicators (as well as others presented in this report).

General characteristics of successful e-infrastructure projects

The IMPACT framework considers five general characteristics of successful e-infrastructure projects (quotes below from Fraunhofer ISI & ZEW 2012: 34, indicators summarised based on ibid. 39-40 and the table below):

Accessibility:

- In brief: *"provide access to scientific data, scientific information (e.g. scientific publications for larger potential set of users) and e-infrastructure capacity based on interoperable, standardized platforms"*;
- Indicators: growth in accessible resources enabled by the e-infrastructure and their user base, geographic and disciplinary origin of the users, including users beyond science.

Efficiency:

- In brief: *"contribute to a more efficient way of working by providing improved or new problem solving infrastructure capacities ('by software and computer instead of hand')"*;
- Indicators: increase of efficiency in scientific work enabled by access to content/data and provision of problem solving tools (e.g. services, software); a gain in efficiency may be that research projects using data from the infrastructure report having produced results faster than expected; problem solving capacity may be indicated by publications referring to tools provided by the e-infrastructure projects.

Innovativeness:

- In brief: *"contribute to fields beyond science by laying down new foundations in ICT and exploring their potential for its use in other areas"*;
- Indicators: pool of available knowledge from providers for different users (e.g. research centres, industry and public sector organizations); novel technical solutions enabled by the e-infrastructure and their use for innovations by research centres and non-scientific users, e.g. innovations reported by the e-infrastructure and users; perceived potential for future industrial innovations.

Sustainability:

- In brief: *"contribute a new dimension of availability by concepts for continuous and sustainable availability of scientific data, information and capacities"*;
- Indicators: follow-up financing for operation and upgrades, institutions carrying on the e-infrastructure, international cooperation maintained, etc.

Transformative character:

- In brief: *"contribute to the transformation process in scientific work towards e-Science through increasing e.g. multidisciplinary or collaboration between researchers of different locations and disciplines transforming the science system and enhancing the human capital for a knowledge economy as provided by most e-Science environments"*;
- Indicators: support of users in addressing research questions not solvable without infrastructure for e-science, promotion of multidisciplinary projects, new research standards produced and disseminated by the e-infrastructure project, result used for teaching/training, increased digital skills of researchers, PhD or Master theses supported by the e-infrastructure.

Table of impact indicators

The table below presents the indicators which the IMPACT report considers as specific for Data Infrastructure and generic ones for all e-infrastructures, i.e. it does not include specific indicators for High Speed Networks, High Performance Computing, Distributed Computing Platforms and e-Science environments (cf. Fraunhofer ISI & ZEW 2012: 58-64 and 161-163). To allow a better coverage of Data Infrastructures also some questions or details from the IMPACT survey questionnaire (ibid., 147-152) are included which did not make it into the final selection of IMPACT indicators for Data Infrastructures.

For these indicators the results of the ARIADNE project are presented. One important point to bear in mind is that the ARIADNE project has successfully implemented a data infrastructure but the services are operative only since about one year. Therefore results for indicators which ask about annual changes (e.g. annual increase in users, access, downloads, etc.) cannot be given; this is possible only after two years of operation. Others can only be estimates. For example, the percentage of users of different categories cannot be given as use of ARIADNE services does not require registration (a situation that is typical also for other data infrastructures). Figures for other impacts are very difficult to collect, for example, publications which benefited from using data made accessible. Therefore our test case will make clear what can or cannot be evaluated by a data infrastructure project that completed the implementation phase as well as what are unrealistic indicators also after one or more years of service provision.

Impact dimensions and indicators	***ARIADNE results***
Accessibility	
Resources and users	
○ Increase of information/data (e.g. number of data records, publications or other) made available for users via the project's infrastructure (in % since project start per year)	1,905,922 records from providers in different EU countries cross-searchable on the ARIADNE data portal Increase 100% (there was no cross-search of the data records before)
○ How many data providers have joined the infrastructure since project start?	16 data publishers (some with many contributors)

○ How many datasets (from the data providers) are available for usage?	24 (some with many sub-sets)
○ Is the infrastructure working with queued jobs/packages or real-time accessibility?	Real-time access
○ Are users charged for using the infrastructure	No charge
○ Change of requests or downloads of resources in % since project start per year	Service operation: 1/2016-1/2017: over 10,800 visitors, 15,400 sessions, 69,000 page views Annual change/increase of requests to be reported after two years of operation
○ How many new end-users register with the infrastructure per year (or no registration necessary to use data)?	No registration on the data portal is required
○ Users from how many different countries are using the infrastructure (Europe and worldwide)?	ca. 90% Europe, 10% other countries (i.e. United States 4.13%, Russia 2.49%)
Access beyond science	
○ Project research/developments and results being used for teaching	Yes, for academic project partners, but hardly for other teaching (e.g. at secondary academic schools) See also indicator "Change of knowledge base" concerning training provided to researchers and practitioners
○ Project results available for the public (in %)	100% of the online accessible data/information resources (e.g. data records, project reports, public presentations, guides to good practice) 86 paper in journals, conference proceedings, book chapters; 48 open access (e-journal/proceedings or self-archived), others accessible via publishers' websites 91 presentations and 26 documents (i.e. deliverables) available on SlideShare, total views 69,270
○ Non-scientific users of industry/businesses, governmental, educational and other institutions, private persons (in %)	Shares cannot be reported as no registration is required to use the data services Registration with information about user background (e.g. industry, governmental, etc.) would be required, but is not intended Estimate: 10% non-scientific users
Efficiency	
○ Increase in new services offered since project start (in % per year)	Dataset registry & portal services: 100% Core services: registration, metadata records aggregation (including several enrichment services), search & browse and visualization, metadata preservation Search services include: Full-text search over the records; multi-lingual keyword/subjects-based, including term

	suggestion; tag cloud based (at entry level, in English, but with multi-lingual results); thematically similar records (within search results); map-based search, including indication of available records when zooming into the map; geographically similar records (within search results), timespan-based search with visual interface for selecting date ranges. Advanced object visualisation and manipulation, if content providers employ offered services for high-resolution images, RTI images, 3D artefact models, 3D terrain and landscape models. Standalone online vocabulary services offered: gazetteer, subject vocabularies (English, Italian, multi-lingual), vocabulary mapping Number of core portal services: 5 (registration, aggregation, search [3: keyword/subjects, map, timespan) Increase of services to be reported after two years of operation; but unlikely many additional services will be developed (maybe 1-2 per year)
○ Increase in number of research projects/publications which benefited from the infrastructure (e.g. access to information/data) since project start	Number of publications can be reported only after 2+ years of operation (because often long timespan until papers are published) Collecting/receiving such information is generally difficult, i.e. no mechanisms to track data users and request information about publications. Information about benefits of known users (e.g. partners, related projects) can be provided
○ Project better than most other facilities, best in field, or the only facility in particular field (self-efficiency assessment)	ARIADNE is the only facility (e-infrastructure) of this kind in the field of archaeology in Europe Compared to other data infrastructures: at least as good, in some respects arguably better (compare their results to the ARIADNE outcomes reported in this table as well as others given in this report)
Sustainability	
Financing and continuation of work	
○ Project plans to continue work	Yes. Continuation of some activities beyond the funded period is planned by the established ARIADNE Association
○ One or more institutions will carry on the work (e-infrastructure) completed by the project	Yes. The e-infrastructure services will be kept running “in-kind” by one major project partner; expansion of datasets and services will depend on new funding
○ Project plans or has applied for new funding	Yes. Submission of proposals for new funding (one already submitted)
Cooperation and collaboration	
○ With institutions / projects in same	European institutions: Involvement of 65 institutions

domain (EU, worldwide)	from 24 EU Member States and 2 from other European countries (Iceland, Norway), 15 formal cooperation agreements 10 European projects, with a focus on e-infrastructure, digital research tools/services, specific datasets and standards Worldwide: 19 liaisons and activities with institutions outside of Europe and international projects (formal cooperation agreements with 6 institutions/projects)
○ With institutions / projects in other domains (EU, worldwide)	Archaeology is a multi-disciplinary field of research with many relevant related domains; in the implementation phase cooperation has been mainly with institutions/ projects in closely related domains of humanities and heritage research (in the future also collaboration with other domains is considered, e.g. life, environmental and social sciences)
○ With other e-Infrastructures projects	Yes: CENDARI (e-infrastructure for European history archives), DARIAH (digital humanities), EUROPEANA (Europeana Research), PARTHENOS (humanities e-infrastructures cluster), ESFRI initiative E-RIHS (heritage sciences)
Innovativeness	
Patents and innovation	
○ Patents announced	No patents from project work by consortium members Technical advances primarily made available open source
○ Users reported patents or innovations linked to the project (e.g. by research centres, governmental institutions, industry or others)	Patents: unknown, but unlikely Innovations: *General:* same situation as for user benefits from access to information/data under "Efficiency" above, i.e. long timespan for innovation by users of novel methods, tools or services *Innovations from underlying technology:* in order to ensure reliability data infrastructures mainly apply/adapt established technical approaches and open standards and software; in this regard the project contributed to the further consolidation of the knowledge and technology applied for data infrastructures *Innovations from novel methods, tools and services:* mainly with regard to data interoperability, specifically semantic models and tools, and visual media services. Example: improved capability of publishers (e.g. e-journals, online repositories, research projects) to offer enhanced access to visual media (e.g. Reflectance Transformation Imaging - RTI, large 3D models) Expected: increased interoperability of data resources based on Linked Data vocabularies and vocabulary mapping tools developed by partners

○ Potential for future innovations based on project work or results (e.g. for industry/businesses as users of, or suppliers for, the infrastructure; for public services, or others)	Possibly progress in archaeological research and businesses through enhanced access to shared knowledge, e.g. fieldwork reports of contract archaeologists and academic research and synthesis Low potential for ICT businesses to provide research e-infrastructure and services (e.g. data archives) for archaeological research (or other fields of research)
Pool of knowledge (origins of consortium and users)	
○ How many members does the project consortium have?	23
○ Research centres/institutes	11 - Research / public bodies: national research councils (2), universities (3), institutes of academies of sciences (4), national research institute (2) 6 – Research / other: foundation (2), association (2), non-profit enterprise (2)
○ Public/governmental bodies	4 – Governmental or other public bodies: ministry (1), national data service (1), national museum (1), other public institute (1)
○ Private firms (industry)	-
○ Other	2 - Higher education establishment, with research function (not public bodies)
○ Users: Research centres/institutes (share)	90% (estimated): public and other research institutes as above; users: i.e. researchers, lecturers and research students in archaeology and cultural heritage
○ Users: Public/governmental bodies (other than above) (share)	3% (estimated): cultural heritage management agencies, museums; users: i.e. heritage management officers, curators of museum collections
○ Users: Private firms (industry) (share)	5% (estimated): contract archaeologists and consultants
○ Users: Other (share)	2% (estimated): non-professional users: people interested in archaeology and cultural heritage
Transformative character	
Change of knowledge base	
○ Project results/developments presented at scientific conferences	67 co-organised conference sessions, workshops, etc. with at least one presentation by a project partner (in most cases more) 151 scientific or other public events attended with at least one presentation by a project partner
○ Project results/developments being used for teaching/education	Yes, by academic/professional project partners, but hardly for other teaching (e.g. not at secondary academic schools)
○ Training and learning resources for project participants (e.g. researchers, operators of RI or others)	Direct support and online helpdesk for dataset preparation & provision to the e-infrastructure 97 Transnational Access (TNA) study visits to partner

	competence centres (summer school format or individual visits of one week); included visits of researchers for own research projects and/or institutional projects (i.e. in view of providing data)
○ Training and learning resources for researcher and others outside of the project (e.g. knowledge and skills for using the project results/e-infra-structure, services, tools; research skills and methods which benefit from new e-infrastructures, etc.)	424 researchers and practitioners participated in 18 tutorials and short courses offered by partners at conferences, workshops, etc. Guides to Good Practice offered online: support knowledge and skills in the creation, management and sharing of various types of data
○ PhD/Master-theses finished/on-going supervised by project members/employees, or based on data available from the project or the infrastructure	Supervision of theses is not part of funded project work; theses based on accessible data are generally possible, but could be identified only after 2- years of operation (same issue as noted for research publications under "Efficiency")
Transformation of science	
○ Project work tackles multiple research disciplines	Cross-repository search and access to data relevant for different domains of the multi-disciplinary field of archaeological research Fosters cross-domain fertilisation between projects; also collaboration of scholars and technologists for new tools/services
○ Project enables possibility to address previously unsolvable research questions with access to infrastructure	Integrated access to archaeological data repositories in Europe, enabling use of data from different countries for comparative studies and synthesis
○ Project develops new research standards (e.g. data formats, software types, software services, processing routines, etc.)	CIDOC-CRM extended from use for heritage documentation to research, e.g. including CRMsci for scientific observations/measurements and CRMarchaeo for excavations
○ Project enables new science degree (e.g. M.Sc, PhD) based on the project work or results	No. Beneficial would be a new degree in information science for e-infrastructures

8 Annex C: Overview of community building activities

Activities	*Symbol*	*Amount*	*Participants*	
Participation in user requirements surveys	ϕ	2	692	692
Events (co-)organised by ARIADNE partners (conference sessions, workshops etc.) and meetings with representatives of institutions and projects to liaise and establish or advance cooperation); events/meetings with at least 1 presentation by a partner (in most cases more)	●	67	3180 (average 47)	12,801 (average 59)
Other conferences, workshops, etc. attended, with at least 1 presentation by a partner	o	151	9621 (average 64)	
Transnational access (TNA) training / summer schools and individual study visits (*individual TNA visits at PIN in 2015 and 2016 counted as 2 training events/schools)	⌂	12*	97 (average: 8)	521 (average 17)
Short training courses, tutorials and hands-on workshops	Δ	18	424 (average 24)	
Total			**14,014**	**14,014**

The total number of 14,014 participants represents project-external people, partners were generally not included in the reported number of participants. However, we assume that the total number includes 25% participation of project-external people in more than one activity.

ARIADNE thus reached and involved about 10,500 researchers, practitioners, students and other people active or interested in archaeological and cultural heritage research and dissemination, particularly with digital content/ data, tools and services. Except of the online user surveys all others where direct, face to face activities. The figure of 10,500 does not include the reach of the project's online information. The number of people involved is 30 times larger than the membership of the Computer Applications and Quantitative Methods in Archaeology (CAA) organisation/conference (350), 5 times larger than the membership of the European Association of Archaeologists (2000+), and about 32% of the number of archaeologists working in Europe (33,000), estimated by the Discovering the Archaeologists of Europe project (DISCO 2014: 6).

Activity	*Type*	*Participants*
2016		
ARIADNE Final Event, Florence, Italy, 15-16 December 2016: With presentations by the president of the European Archaeological Council, the president of the European Association of Archaeologists, DARIAH-EU, E-RIHS (new ESFRI project), and all ARIADNE partners	●	120
PARTHENOS Symposium, Prato, Italy 14 December 2016: networking event, including a presentation by PIN on common services of ARIADNE and PARTHENOS	o	50
Legacy Datasets and their Inclusion in the ARIADNE Registry, TNA Winter	⌂	15

School at PIN, Prato, 12-14 December 2016		
Virtual Heritage Network Conference, Cork, Ireland, 10 December 2016: Paper by Evie Monaghan & Rónán Swan "Collaboration in Digitising Cultural Heritage: Transport Infrastructure Ireland's Heritage Collection and the wider European Context", Discovery	O	80
Workshop on the Archaeological Map of Bulgaria, Sofia, Bulgaria, 8-10 December 2016: Incl. presentation of the ARIADNE project and outcomes; workshop organised by NIAM-BAS	●	50
Digitális régészet - A Magyar emzeti Múzeum Adatbázisa (Digital Archaeology - The Hungarian National Museum Archaeology Database), Budapest, Hungary, 5 December 2016: organised by the Hungarian National Museum	●	100
CHNT 2016 - 21th International Conference on Cultural Heritage and New Technologies, Vienna, Austria, 16 November 2016: ARIADNE session "Preservation as a foundation for the reuse of data" (organised by ADS, KNAW-DANS, IANUS/DAI) and Roundtable "Where is an archive for my data?" (organised by ÖAW-OREA and SRFG), 75 session participants (29 in the roundtable)	●	75
ArcheoVirtual 2016 EXPO, Paestum, Italy, 27-30/10/2016: Is the annual event presenting virtual archaeology projects within the Mediterranean Expo of Archaeological Tourism. ArcheoVirtual has been organised since 2006 by CNR-ITABC/VHlab. CNR-ITABC presented the Virtual Museum of Calore Valley, Avellino, Italy built with ARIADNE landscape services	●	60
Les rencontres de la TGIR Huma-Num, Lyon-Ecully, France, 10-13 October 2016: Presentations on harmonization of open access policies among research infrastructures (S. Di Giorgio, MiBAC-ICCU), and use of the ARIADNE 3M mapping tool (G. Bruseker, FORTH-ICS)	O	80
14th Eurographics Workshop on Graphics and Cultural Heritage, Genova, Italy, 5-7 October 2016: Workshop organised by CNR-ISTI	●	50
Conference on Language Technologies & Digital Humanities 2016, Ljubljana, Slovenia, 29.9.-1.10.2016: Conference with a with a focus on the research community in the Western Balkan region; presentation on ARIADNE: Linked Open Data in practice, by B. Štular, who also was a member of programme committee, ZRC-SAZU	●	50
Das Digitale und die Denkmalpflege, Weimar, Germany, 29-30 September 2016: Presentation on 3D technology development with a focus on the ARIADNE approach to infrastructure services for visual media, R. Scopigno, CNR-ISTI	O	80
World Archaeology Congress, Kyoto, Japan, 29 September 2016: Presentation on sharing data in the Digitizing Early Farming Cultures project, ÖAW-OREA	O	40
Colloque MASA 2016: Archivage, publication et mise à disposition de données archéologiques, Nanterre, France, 26-27 Septembre 2016: Conference of the Consortium Mémoires des Archéologues et des Sites Archéologiques (MASA), one of the consortia of the HUMA-NUM research infrastructure; presentation on Digital Preservation and Access in a European Perspective: Introducing ARIADNE by J. Richards (ADS) and	O	80

Federico Nurra (Inrap)		
15th European Networked Knowledge Organization Systems (NKOS) Workshop, held during the TPDL 2016 Conference in Hannover, Germany, 9 September 2016: co-organised by USW	●	40
Aerial Archaeology Research Group (AARG) Conference 2016, Pilsen, Czech Republic, 7-9 September 2016: presentations on the state of the art in aerial data acquisition, management and interoperability; organisation and presentations by ARUP-CAS	●	60
ARQUEOLÓGICA 2.0 - 8th International Congress on Archaeology, Computer Graphics, Cultural Heritage and Innovation, Valencia, Spain, 5-7 September 2016: Poster on Putting 3D Models in Context, ÖAW-OREA	O	40
EAA 2016 - 22th Annual Meeting of the European Association of Archaeologists, Vilnius, Lithuania, 1 September 2016: ARIADNE session "Open Access and Open Data in Archaeology: Following the ARIADNE thread", organised by ADS and SRFG; presentations by ADS, AIAC, Athena-DCU and SRFG	●	30
Central European Conference of Historical Geographers, Prague, Czech Republic, 31.8.-2.9.2016: Invited paper by M. Kuna, ARUP-CAS	O	80
CIDOC-CRM SIG meeting, Heraklion, Crete, Greece, 1-4 August 2016: Meeting held at FORTH-ICS, presentation of the last version of CRMarchaeo and the new CRMtex extension for describing ancient texts (papyri, inscriptions and so on) by PIN researchers	●	20
Seventh International Workshop on Computational Models of Narrative, Krakow, Poland, 11-12 July 2016: Paper on steps towards a formal, CIDOC-CRM based ontology of narratives by researchers of CNR-ISTI	O	50
International Advisory Board Meeting of the Project DATABENC - CHIS (Cultural Heritage Information System), Salerno and Naples, Italy, 7-8 July 2016: Participation of F. Niccolucci (PIN) and R. Scopigno (CNR-ISTI) as board members, presentation of ARIADNE and its design & policy for cultural heritage infrastructure services	O	50
Design of archaeological datasets - CNR-ISTI(NeMIS), Pisa, Italy, ARIADNE summer school, 4-8 July 2016	⌂	6
ICOM conference, Milan, Italy, 5 July 2016: Presentation of CRMarchaeo at ICOM CIDOC workshop by PIN	O	20
Archaeological Information in the Digital Society (ARKDIS) conference, Uppsala, Sweden, 1 July 2016: Presentation on digital archiving and interoperability initiatives by J. Richards, ADS	O	20
European Union Projects' Information Day, Budapest, 28 June 2016: Presentation on the aims and structure/working principles of the Hungarian Archaeology Database and the ARIADNE Portal, MNM-NOK	O	70
Chance or Challenge: Metal Detector Finds in Heritage Practice and Research, Aarhus, Denmark, 23 June 2016: Meeting on the development of European databases of metal-detector finds, participants from Belgium, Denmark, Finland, The Netherlands and UK; presentation by J. Richards, ADS	O	10

Landscape and Archaeology, UNISCAPE En-route International Seminar, Fano, Italy, 23-25 June 2016: Presentation 'Dalla pianificazione alla valorizzazione del patrimonio diffuso', proposed the ARIADNE Landscape Services for representing landscapes in virtual museums, S. Pescarin, CNR-ITABC	o	100
2D/3D documentation for archaeology - CNR-ISTI(VC-Lab), Pisa, Italy, ARIADNE summer school/transnational access, 20-24 June 2016	⌂	6
Design of archaeological datasets - Athena-DCU, Athens, Greece, ARIADNE TNA/summer school, 12-17 June 2016; the summer school included the ARIADNE Expert Forum: The Future of Archaeological Knowledge Curation 2021-2026 (16-17 June) in which senior and young researchers participated (7 TNA + 13 other forum participants)	⌂	20
RCIS 2016 - Tenth IEEE Conference on Research Challenges in Information Science, Grenoble, France, 1-3 June 2016: Presentation "Using Model Views to Assist with Model Conformance and Extension", CSIC-Incipit	o	40
Computer Application in Archaeology 2016, Velké Pavlovice, Czech Republic, 30 May - 1 June 2016: Presentations/papers by ARUP-CAS (M. Gojda, L. Culikova, M. Kuna, D. Krivankova),	o	70
LV National archaeological conference, Stara Zagora, Bulgaria, 27 May 2016: Presentation on the Archaeological Map of Bulgaria, conference co-organised by NIAM-BAS	●	50
Introducing ARIADNE to the Hungarian Excavation Committee, Budapest, 23 May 2016: Presentation on the aims and structure/working principles of the Hungarian Archaeology Database and the ARIADNE Portal, MNM-NOK	o	10
Workshop "Hungarian National Museum Archaeology Database: structure, content, relation to ARIADNE", Budapest, Hungary, 4 May 2016: Introduced the HNM Archaeology Database and ARIADNE Portal to archaeologists; organised by MNM-NOK	●	30
10th International Congress on the Archaeology of the Ancient Near East, Vienna, Austria: Workshop: "Old Excavation Data – What can we do?", 28 April 2016, organised by OEAW-OREA	●	40
Giorno della solidarieta' 2016, Pisa, Italy, 27 April 2016: under the theme "Archaeology: how to document and restore war destructions?" ARIADNE services were presented to high-school students, CNR-ISTI	o	125
The "Other" School, Timisoara, Romania, 18-22 April 2016: archaeological activities with high school students, incl. discussion about Romanian archaeology in the European context, organised by ARHEO	●	80
Workshop "Open Access and Archaeological Databases: Ariadne, Fasti Online and the North African Heritage Archive Network", 19 April 2016, Institut für Klassische Archäologie, Ludwig Maximilians Universität Munich, Germany; workshop directed by L. Fentress, AIAC	●	16
Durham Conference 2016, Durham, UK, 15-17 April 2016: Paper/poster "The first Early Medieval mega-sites in Bohemia" (M. Kuna), ARUP-CAS	o	80
DACII de la Munte - DACII de la Campie Exhibition, Timisoara, Romania, 14 April 2016: Discussion with archaeologists and research students about	●	50

archaeology in Romania and the ARIADNE project, ARHEO		
Italian-German workshop on Technology and infrastructures for Cultural Heritage, Bode Museum, Berlin, 12 April 2016: Presentations by CNR-ISTI, DAI, MiBAC-ICCU and PIN, e.g. F. Niccolucci, PIN on "ARIADNE and PARTHENOS projects"	O	100
Annual Congress of the Society for American Archaeology, Orlando, Florida, 9 April 2016: Symposium What Do We Mean by "Digital Curation?", organised by ADS (J. Richards) and Digital Antiquity (F. McManamon), with participation of United States digital archaeology centres/projects and archives; two presentations on ARIADNE by ADS (J. Richards, H. Wright); distribution of the current ARIADNE leaflet at the congress	●	60
European Open Science Cloud (EOSC) - Third community workshop: Connecting users and providers in the EOSC, Amsterdam, 7 April 2016: Prof. F. Niccolucci (PIN) participated on behalf of PARTHENOS (humanities RIs cluster) and ARIADNE.	O	50
Best Practice in Conservation in the Arab Region Exhibition 2016, ICCROM-ATHAR Regional Conservation Centre in Sharjah, United Arab Emirates, 7 April 2016: presentation of Fasti Conservation and ARIADNE to regional archaeologists and heritage conservators, AIAC	O	30
North African Heritage Archive Network – NAHAN meeting, German Archaeological Institute, Berlin, 5 April 2016: follow-up meeting at DAI to advance the partnership and establish cooperation agreements	●	6
CAA 2016, Oslo, Norway, 31 March 2016: Round Table "Unstable futures/Potential pasts: scenarios for digital computing 2020", co-organised by Athena-DCU (A. Benardou and C. Dallas)	●	12
CAA 2016, Oslo, Norway, 30 March 2016: ARIADNE session "Supporting researchers in the use and re-use of archaeological data: continuing the ARIADNE thread", presentations by ADS, AIAC, CNR-ISTI, CyI-STARC, CSIC-Incipit, DAI, FORTH-ICS, Inrap and PIN	●	40
CAA 2016, Oslo, Norway, 30 March 2016: Session "Archaeological Information Languages and Notations", organised by CSIC-Incipit; presentation "Is that a good concept?" by FORTH-ICS *et al*.	●	40
CAA 2016, Oslo, Norway, 30 March 2016: Session "Linked pasts: Connecting islands of content": Presentations "Linking periods: Modeling and utilizing spatio-temporal concepts in the chronOntology project", S. Cuy *et al*., DAI; "The Matrix: Connecting time and space with archaeological research questions", K. May, USW/English Heritage	O	20
CAA 2016, Oslo, Norway, 30 March 2016: Session "Documentation, interpretation and communication of Digital Archaeological Heritage": Presentation "A methodology for the analysis of graphical representations in archaeology and some preliminary results", R. Varela, Incipit CSIC	O	30
Seminar at Podgorica University, Historical Institute of Montenegro, Podgorica, Montenegro, 25 March 2016: Seminar of the KATUN project, plans to use ARIADNE web-services, CNR-ITABC	O	20
European Archaeological Council - Annual Meeting & Heritage	O	60

Management Symposium 2016, “Digital Archaeological Heritage”, Brighton, UK, 17-18 March 2016: Participation of EAC members from most European countries; presentations by ARIADNE archive partners ADS and DANS, ARUP-CAS on the Archaeological Map of the Czech Republic, and MNM-NOK on the use of digital tools in preventive archaeology		
RAC 2016 - 12th Roman Archaeology Conference, Rome, Italy, 17 March 2016: discussion of open data in survey archaeology and presentation of Fasti Survey as an initiative in the context of ARIADNE, AIAC	o	50
ESFRI Roadmap 2016 - Launch Event, Amsterdam, 10 March 2016: Participation & networking by ARIADNE coordinator prof. F. Niccolucci, PIN	o	60
Conference “The voice of the rock”, Lyubimets, Bulgaria, 5 March 2016: Presentation of ARIADNE to researchers and state officials, NIAM-BAS	o	20
Joint meeting of CIDOC-CRM SIG, ISO/TC46/SC4/WG9 and FRBR CIDOC-CRM Harmonization group, Prato, Italy, 24-26 February 2016: Meeting held at PIN, presentations by PIN researchers on using the CRM for archaeological science, ancient texts, expressing reliability with the CRM, also the CRM mapping and browsing assistant was presented	●	30
North African Heritage Archive Network – NAHAN meeting, École française de Rome, 22 February 2016: project focused on sharing reports/data from excavations and surveys in the Maghreb region of western North Africa; meeting of directors of archives and research institutes from Algeria, France, Italy, Marocco, Spain, Tunisia, UK; organisation and participation of AIAC, DAI and PIN in a leading role	●	15
3D Data: Access & Reuse, Llandudno, Wales, UK, 11 February 2016: Presentation on 3D data access methods including information on ARIADNE tools (e.g. CNR-ISTI tools) and the data portal, Discovery	o	150
Estudio, conservación y restauración del patrimonio cultural y arqueológico: Tecnologías e infraestructuras para la investigación en Ciencia del Patrimonio, Mexico City, Mexico, 2-3 February 2016 : Presentation of ARIADNE project: "El Componente Digital de las Infrastructuras de Investigación sobre el Patrimonio”, PIN	o	80
Meeting at Gyula Forster National Centre for Cultural Heritage Management, Budapest, 28 January 2016: as a follow-up to the first meeting in January 2015 MNM-NOK (A. Kreiter) presented ARIADNE to the centre’s registry office and put forward a plan to integrate their archaeological sites into the ARIDNE data catalogue	●	3
NIAM-BAS General Assembly, Sofia, Bulgaria, 28 January 2016: Report on work done in ARIADNE and opportunities to participate in activities, NIAM-BAS	●	100
Delavnica arhiviranja digitalnih podatkov, Ljubljana, Slovenia, 21 January 2016: Data management workshop for archaeologists and heritage professionals, held at ZRC-SAZU with presenters from ADS and PIN	Δ	38
Datenmanagement in der Archäologie, Vienna, Austria, 19 January 2016: Data management workshop for archaeologists and heritage professionals, held at ÖAW-OREA with presenters from ADS and PIN	Δ	42
Archaeological Institute of America, Annual Meeting, San Francisco, 6-9	●	12

January 2016: AIAC team members met with several projects, resulting e.g. in the signing of a cooperation agreement with MAGIS – Mediterranean Archaeology GIS (a database of surveys in the Mediterranean since 1980)		
Master course in Archaeological Heritage, Central European University, Department of Medieval Studies, Budapest, 11 January 2016: Presentation "The Preservation and Re-use of Archaeological Data" and promotion of ARIADNE to postgraduate students, heritage professionals and key personnel in Hungarian archaeology, J. Richards, ADS	o	30
Mapping existing datasets to CIDOC-CRM - PIN, Prato, Italy, 2016, individual transnational study visits and training of 3-5 days	⌂	6
2015		
DARIAH Ireland Group Meeting, Dublin, Ireland, 16 December 2015: Update of the DARIAH Group on how to collaborate with ARIADNE, Discovery	o	10
Science and Innovation for the Study and Conservation of Works of Art, Buenos Aires, Argentina, 1-2 December 2015: Presentations "The digital component of research infrastructures for cultural heritage", F. Niccolucci, PIN, and "Digital technologies for visual documentation and presentation", R. Scopigno, CNR-ISTI, addressing the ARIADNE infrastructure and visual media services	o	120
ArheoVest Symposium "Interdisciplinarity in Archaeology and History", Timisoara, Romania, 28 November 2015: ARIADNE was one of the topics related to data management and dissemination (e.g. ARIADNE data catalogue, 2D/3D tools, and guidance on good practices), ARHEO	●	200
Reuvensdagen, Zwolle, the Netherlands, 26 November 2015: Presentation of ARIADNE in Session: "Malta voorbij: nieuwe ontwikkelingen en initiatieven in Europa", KNAW-DANS	o	60
CAA Sweden conference 2015, Umeå, Sweden, 10 November 2015: Presentation of ARIADNE and related topics, SND	o	40
CIDOC-CRM Mapping Workshop for Humanities Scholars and Cultural Heritage Professionals, Oxford e-Research Centre, UK, 9-10 November 2015: FORTH-ICS (M. Theodoridou) in cooperation with British Museum (D. Oldman, ResearchSpace)	Δ	25
Joint meeting of CIDOC-CRM SIG, ISO/TC46/SC4/WG9 and FRBR CIDOC-CRM Harmonization, Heraklion, Crete, 6-9 October, 2015: co-org. by FORTH-ICS; presentations by C. Meghini (CNR-ISTI): Formalization of the CRM: A first-order attempt; M. Theodoridou (FORTH-ICS): Mapping Culture Semantically with CIDOC-CRM & 3M; A. Felicetti (PIN): Conceptual Spaces: Organising Geographical Knowledge; CIDOC-CRM and Epigraphy, and P. Ronzino (PIN): CRMba and CRMarchaeo models harmonization	●	23
Segundo Congreso Internacional de la Sociedad de Humanidades Digitales Hispánicas (HDH 2015), Madrid, Spain, 7 October 2015: Presentation "A Modelling Language for Discourse Analysis in Humanities: Definition, Design, Validation and First Experiences", CSIC-Incipit	o	90
Segundo Congreso Internacional de la Sociedad de Humanidades Digitales	o	35

Hispánicas (HDH 2015), Madrid, Spain, 6 October 2015, Presentation "Teaching Conceptual Modelling in Humanities and Social Sciences", CSIC-Incipit		
IV Convegno di studi SITAR, Rome, Italy, 14 October 2015: Presentation of the ARIADNE project to members of the Italian community of archaeologists, MiBAC-ICCU	●	150
EAGLE Conference, Nicosia, Cyprus, 3 October 2015: Presentation of ARIADNE activities: Mapping Tools and Interoperability, PIN	O	40
International Colloquium Communication and Culture within Romance Space (CICCRE), 4th edition, Timisoara, Romania, 2-3 October 2015: Presentation by ArheoVest on their work in ARIADNE	O	100
Workshop on data sharing in Italy, "L'integrazione dei dati archaeologici digitali. Esperienze e prospettive in Italia", Lecce, Italy, 1 October 2015: the aim of the workshop was to share and compare Italian experiences on online archaeological data sharing, in view of a national initiative that proposes the creation of an integrated system based on the ARIADNE approach, organised by PIN; presentation of ARIADNE activities and achievements, PIN; presentation by CNR-ISTI, "Il registry di ARIADNE e il modello di metadata"	●	30
Digital Heritage International Congress 2015, Granada, Spain, 1 October 2015: Presentation "Alchemy in 3D: A Digitization for a Journey Through Matter", CNR-ISTI	O	25
Digital Heritage International Congress 2015, Granada, Spain, 1 October 2015: Presentation "Digitizing Early Farming Cultures. Customizing the Arches Heritage Inventory & Management System", OEAW-OREA	O	30
Digital Heritage International Congress 2015, Granada, Spain, 29 September 2015: Presentation "A Puzzle in 4D: Digital Preservation and Reconstruction of an Egyptian Palace", OEAW-OREA	O	40
Digital Heritage International Congress 2015, Granada, Spain, 28 September 2015: Tutorial "3DHOP - Presenting Online High-res 3D Models: a Crash Course", CNR-ISTI	Δ	25
Promoting ARIADNE in Hungary, September-October 2015: MNM-NOK contacted over 100 archaeologists/scientists at various institutions with the aim to make available grey literature of sites they excavated/analysed through ARIADNE, MNM-NOK	●	100
YorNight - European Researchers Night, York, UK, 25 September 2015: (a YorNight is large event which aims to show that research is fun and influences daily life for all of us; demonstration of 3DHOP, ADS	O	50
TPDL 2015 – 19th Intern. Conference on Theory and Practice of Digital Libraries, Poznan, Poland, 18 September 2015: 14th European Networked Knowledge Organization Systems (NKOS) Workshop, co-organised by USW; 4 presentations directly relevant to ARIADNE (USW on mapping work, PIN on CRM time modeling, DAI on data mapping and use of PeriodO periods in ARIADNE	●	30
TPDL 2015 - 19th Intern. Conference on Theory and Practice of Digital Libraries, Poznan, Poland, 17 September 2015: Workshop "Extending,	●	25

Mapping and Focusing the CRM", (co-)organised by PIN		
Reconstruction of the Archaeological Landscape through Virtual Reality, Rome, Italy, training school, 8-11 September 2015: Included training on two days on how to use the ARIADNE Landscape Services, CNR-ITABC	Δ	21
AARG - Aerial Archaeology Research Group, Annual Conference, Santiago de Compostela, Spain, 9 September 2015, co-organiser CSIC-Incipit: Presentation of ARIADNE and its relevance to remote sensing Data; Discovery & ZRC-SAZU	●	100
EAA 2015 - 21th Annual Meeting of the European Association of Archaeologists, Glasgow, UK, 5 September 2015: Presentation "The value of complementarity. Integrating traditional and modern ways in archaeological remote sensing", ARUP-CAS	o	40
EAA 2015 - 21th Annual Meeting of the European Association of Archaeologists, Glasgow, UK, 5 September 2015: Presentation "Standards for 3D documentation in archaeology", PIN	o	60
EAA 2015 - 21th Annual Meeting of the European Association of Archaeologists, Glasgow, UK, 3 September 2015: Presentation of ARIADNE within round table session on the sharing and re-use of spatial data in archaeology & cultural heritage, Discovery	o	35
Linked Pasts colloquium, King's College London, UK, 20-21 July 2015: organised under the auspices of Pelagios, a collective of some of the most effective Linked Open Data (LOD) projects in cultural heritage and the humanities; ARIADNE partners presented an overview of the project and on-going work on Linked Data vocabularies, ADS and USW	o	75
ISKO-UK biennial conference, UCL London, 14 July 2015: Presentation on vocabulary mapping and linked data by USW	o	50
Design of archaeological datasets - CNR-ISTI(NeMIS), Pisa, Italy, ARIADNE summer school/transnational access, 6-10 July 2015	⌂	5
Digital Heritage Workshop 2015, York, UK, 8 July 2015: Presentation "3D Web-Based Dynamic Platforms in Archaeology: Combining offline and online datasets to gain new understanding of the archaeological record", ADS	o	40
Design of archaeological datasets - Athena-DCU, Athens, Greece, ARIADNE TNA/summer school, 28 June - 3 July 2015; the summer school included the Expert Forum: Digital Futures of Archaeological Practice 2020-2025 (2-3 July) in which senior and young researchers participated (6 TNA +16 other forum participants)	⌂	22
Digital Preservation for the Arts, Social Sciences and Humanities (DPASSH 2015), Dublin, Ireland, 25-26 June 2015: Conference on safeguarding the social and cultural record of Ireland; presentation on archaeology data strategies and ARIADNE (a paper published in New Review of Information Networking, vol. 20), Discovery	o	200
2D/3D documentation for archaeology - CNR-ISTI(VC-Lab), Pisa, Italy, ARIADNE summer school/transnational access, 22-26 June 2015	⌂	8
Scientific Communications annual session, Deva, Romania, 11-12 June	o	100

2015: Presentation “135 years from establishing the history and archaeology society of Hunedoara’s county”, ARHEO		
5° Seminario Internacional de Patrimonio Cultural Inmaterial: Informática Cultural, Valparaíso, Chile, 25-27 May 2015: Keynote “Humanidades digitales, tecnologías semánticas, y co-investigación en patrimonio cultural”, CSIC-Incipit	O	150
Digital Heritage Conference 2015: Center for Digital Heritage, Aarhus, Denmark, 21-22 May 2015: Presentations by ADS and CNR-ISTI (implementation of a 3D viewer on the ADS repository), CyI and PIN (on knowledge representation of 3D virtual reconstructions)	O	120
CIDOC-CRM SIG Meeting, Nürnberg, Germany, 20 May 2015: Co-organised by FORTH-ICS, presentations on CIDOC-CRM and extensions (FORTH-ICS) and the CRMarchaeo model (PIN)	●	30
Conference: Identità Digitale Unica, Lecce, Italy, 15 May 2015: Presentation of the ARIADNE project, PIN	O	120
RCIS 2015 - Ninth IEEE International Conference on Research Challenges in Information Science, Athens, Greece, 13- 15 May 2015: Presentation “Automatic Process Model Discovery from Textual Methodologies: An Archaeology Case Study”, Incipit CSIC	O	50
Meeting with politicians (TD & Senators) of Ireland, Dublin, Ireland, 13 May 2015: Raising awareness on the importance of digital archives and e-infrastructure, Discovery	●	80
National symposium of Valea Alunului, 2nd edition, Alun, Romania, 8-10 May 2015: “Archeological site or historical landscape - theory and practice in field archaeological research”, ARHEO	O	200
Digital Archaeology: National Conference, Amersfoort, Netherlands, 21 April 2015: Presentation of ARIADNE and the Data Seal of Approval for trusted digital repositories, KNAW-DANS	O	40
CLARIN ESFRI project directors meeting, Utrecht, Netherlands, 18 April 2014: Presentation of ARIADNE, PIN	O	5
RCC / Netherlands Cultural Heritage Agency Symposium, Amersfoort, Netherlands, 16 April 2014: participation of officers from RCE and researchers from Dutch Universities, presentation of ARIADNE, PIN	O	60
Annual Meeting of the Society for American Archaeology 2015, San Francisco, USA, 17 April 2015: Symposium “Open Methods in Archaeology”, presentations by J. Richards (ADS) “Encouraging Open Methods via Data Repositories” and F. Galeazzi (CNR-ISTI), “ADS 3D Viewer: An Example of Open 3D Real-Time Visualization System in Archaeology”	O	50
CAA 2015, Siena, Italy, 2 April 2015: Round table “Challenging Digital Archaeology – the Discussion Continues”, presentation “Data Is Not Enough, Let’s Aim for Knowledge”, CSIC-Incipit	O	20
CAA 2015, Siena, Italy, 2 April 2015: ARIADNE session “Supporting researchers in the use and reuse of archaeological data: following the ARIADNE thread”, seven presentations by ARIADNE partners, ADS, Athena-	●	80

DCU, CNR-ISTI, CyI-STARC, FORTH-ICS & OEAW, PIN and USW		
CAA 2015, Siena, Italy, 2 April 2015: Session "Modelling the Archaeological Process", chaired by C. Gonzalez-Perez & P. Martín-Rodilla, CSIC-Incipit: Presentations "A 3D visual and geometrical approach to epigraphic research", CyI-STARC (related EAGLE project); "Documenting and reasoning about research on ancient Corinthia using the NeDiMAH Methods Ontology", Athena-DCU (related NeMO project)	●	40
CAA 2015, Siena, Italy, 1 April 2015: Session "Managing archaeological 3D models", co-organised by PIN, presentation on 3D management for cultural heritage	●	30
CAA 2015, Siena, Italy, 1 April 2016: Session "Towards a Theory of Practice in Applied Digital Field Methods", presentation "A Conceptual and Visual Proposal to Decouple Material and Interpretive Information about Stratigraphic Data", CSIC-Incipit	o	50
CAA 2015, Siena, Italy, 31 March 2015: Session "Linked Data: From interoperable to interoperating": Presentations "Connecting Cultural Heritage Data: The Syrian Heritage Project in the IT infrastructure of the German Archaeological Institute", DAI (P. Gerth & S. Cuy); "From interoperable to interoperating Geosemantic resources", USW (P.J. Cripps & D. Tudhope)	o	40
CAA 2015, Siena, Italy, 30 March 2015: Workshop "Reconstructing Ancient Landscape in the Cloud", CNR-ITABC	Δ	45
CAA 2015, Siena, Italy, 30 March 2015: Workshop "3DHOP - Presenting Online High-res 3D Models: a Crash Course", CNR-ISTI	Δ	65
CAA 2015, Siena, Italy, 30 March 2015: Workshop "Hands-on Archaeological Conceptual Modelling 2", CSIC-Incipit	Δ	20
European Archaeological Council - Annual Meeting & Heritage Management Symposium 2016, Lisbon, Portugal, 18 March 2015: EAC Archaeological Archiving Working Group meeting, presentation on "Archaeological archives and field data management in the Czech Republic" by M. Kuna *et al*. (paper in proceedings), ARUP-CAS	o	50
Fifth EAGLE International Event 2015, "Use and Re-Use of Digital Cultural Heritage Assets – Interoperability, Repositories and Shared infra-structures", Nicosia, Cyprus, 11-12 March 2015, co-organised by CyI-STARC, presentation of ARIADNE	o	45
STVDIVM - School of Archaeological Data in Pompei, EC-funded Open Pompei project in collaboration with the Italian Ministry of Cultural Heritage and the Superintendency of Pompei, Pompeii, Italy, 6-8 March 2015: Keynote by J. Richards (ADS) on Open Data in European Archaeology and ARIADNE	o	30
E-RIHS - European Research Infrastructure for Heritage Science, Rome, Italy, 5 March 2015: Presentation of the ARIADNE project, PIN	o	40
Workshop "Accesso aperto al patrimonio culturale digitale e linked open data: strategie, progetti e nuove opportunità", Rome, 3 March 2015, presentation of ARIADNE, PIN	o	120

CIDOC-CRM SIG 2015 meeting, e-Research Centre, Oxford University, UK, 11 February 2015: Co-organised by FORTH-ICS, discussion of CRMarchaeo, CRMsci and CRMinf (FORTH-ICS), presentation "CIDOC-CRMba: A CRM extension for buildings archaeology information modelling", P. Ronzino, PIN	●	27
SEAHA training course, Pisa, Italy, 22-23 January 2015: PhD students from the University of Brighton visited CNR-ISTI for a training course on visual technologies; the young researchers participate in a programme of SEAHA - Centre for Doctoral Training in Science and Engineering in Arts Heritage and Archaeology (UK)	Δ	3
Meeting at Gyula Forster National Centre for Cultural Heritage Management, Budapest, 18 January 2015: The Forster Centre operates under the Ministry of Human Resources and has a prime responsibility to register, curate, monitor, and develop movable and immovable cultural heritage artefacts and sites of Hungary; the Centre holds the largest database of archaeological sites in Hungary; presentation of ARIADNE and invitation to contribute data to ARIADNE; MNM-NOK	●	5
Mapping existing datasets to CIDOC-CRM - PIN, Prato, Italy, 2015 individual transnational study visits and training of 3-5 days	⌂	7
2014		
First Cultural Heritage and New Technologies International Congress, National Museum of Anthropology, Mexico City, 3-6 December 2014, organised by the National Institute of Anthropology and History (INAH), the conference involved 167 authors from 20 countries such as Colombia, Peru, Guatemala, Chile, Bolivia, Poland, Italy, UK and Mexico, among others, with a total of 88 presentations; participation/presentation of ARIADNE by PIN	o	80
Save the data! - Workshop on Digital Repositories, Vienna, Austria, 2 December 2014; organised by ÖAW-OREA as part of the Digital Humanities Austria conference 2014, presentations by ADS, KNAW-DANS, PIN and ÖAW-OREA	●	50
Lo scavo archeometrico (the archaeometric excavation), Rovereto, Italy, 28 November 2014: CNR-ITABC (invited speaker) presented ARIADNE and the CNR web services for archaeological 3D landscapes, sites and objects	o	50
Reuvensdagen, The Hague, Netherlands, 20 November 2014 (about 600 participants): Poster/presentation at the national conference for Dutch archaeologists, KNAW-DANS	o	120
Research Infrastructures and e-Infrastructures for Digital Cultural Heritage Conference, Rome, Biblioteca Nazionale Centrale di Roma, 13-14 November 2014, Rome; co-organised by ARIADNE and the Italian Ministry of Culture, in the framework of the Italian EU Presidency semester; the conference involved EU projects on infrastructures and e-infrastructures for cultural heritage; the afternoon of the second conference day was devoted to a workshop on the ARIADNE Infrastructure (several presentations); 300+ registered participants	●	200
Joint workshop between PIN and the ARCHES developer team (Getty Conservation Institute/Word Monuments Funds and the Farallon	●	10

Geographics team), Prato, Italy, 10 November 2014: Presentation of ARIADNE activities and discussion about collaboration, PIN		
Mediterranean Exchange of Archaeological Tourism, Paestum, Italy, 30 October 2014: “Opportunities within the ARIADNE network”, introduced participants to the TNA training offer and online services, PIN, CNR-ISTI, Athena-CETI	Δ	5
12th Eurographics Workshop on Graphics and Cultural Heritage, Darmstadt, Germany, 6-9 October 2014: Presentation of scientific papers and a state of the art report, CNR-ISTI	o	60
Deutscher Archäologiekongress, Berlin, 8 October 2014: Sektion des DAI and IANUS: „Wohin mit meinen Daten? Zum langfristigen Umgang mit Forschungsdaten in den Altertumswissenschaften“, presentations by J. Richards (ADS) “Measuring the impact of long term archaeological data archiving and re-use” and D.V. Gilissen (DANS) “Dutch archaeological data depositing, processing, archiving and accessing at DANS”	o	30
Risorse digitali e strumenti collaborativi per le Scienze dell'Antichità, Venice, Italy, 2 October 2014: ARIADNE presentation by PIN	o	90
CIDOC-CRM SIG Meeting, Heraklion, Greece, 29/9-2/10/2014: organised by FORTH-ICS, presentations by CNR-ISTI and FORTH-ICS (e.g. “CRMarchaeo: the Excavation Model - An Extension of CIDOC-CRM to support archaeological excavations”)	●	15
DCH-RP - Digital Cultural Heritage Roadmap for Preservation conference, Rome, Italy, 22 September 2014: Presentation of ARIADNE, PIN	o	40
EAA 2014 - 20th Annual Meeting of the European Association of Archaeologists, Istanbul, Turkey, 13 September 2014: Session “Open Access and Open Data in Archaeology”, 16 presentations, incl. by English Heritage, SRFG and UoY (co-chairs)	●	30
Semantics & Cultural Heritage Meet-up at The British Museum, London, UK, 12 September 2014: Presentation “Mapping the dFMRÖ coin database to CIDOC-CRM”, FORTH-ICS and OEAW	o	20
EAA 2014, Istanbul, Turkey: ARIADNE workshop, 11 September 2014: “Opportunities within the ARIADNE network”, introduced participants to the TNA training offer and online services, Athena-CETI, CNR-ISTI, PIN	Δ	10
CIDOC Annual Conference 2014: Access and Understanding - Networking in the Digital Era, Dresden, Germany, 7 September 2014: Tutorial on CRMsci and CRMarchaeo, FORTH-ICS	Δ	10
Design of archaeological datasets – CNR-ISTI(NeMIS), Pisa, Italy, ARIADNE summer school/transnational access, 14-18 July 2014	⌂	3
A Future for our Past - Research in Digital Technologies for Arts, Heritage and Archaeology, Brighton, UK, 11 July 2014: Invited talk and presentation on ARIADNE, CNR-ISTI	o	100
Electronic Visualisation and the Arts - EVA 2014, London, UK: ARIADNE workshop, 10 July 2014: “Learning Opportunities for Sharing Data in the ARIADNE Project”, introduced participants to the TNA training offer and online services, PIN	Δ	5

DH2014 - Digital Humanities conference, GeoHumanities SIG meeting, Lausanne, Switzerland, 8 July 2014: Presentation: “Effective design and use of a Spatiotemporal Gazetteer”, DAI	o	20
ARCHES Community workshop, Apsley, England, 30 June - 3 July 2014: Presentation of ARIADNE, PIN; participants: culture professionals and software developers	o	30
2D/3D documentation for archaeology - CNR-ISTI(VC-Lab), Pisa, Italy, summer school/transnational access, 23-27 June 2014	⌂	9
Tecnologie digitali per i beni cultural, Rome, Italy, 20 June 2014: Presentation of ARIADNE, CNR-ISTI	o	120
European Network for Archaeology and Integrated Landscape Research: workshop, Glasgow, UK, 11-13 June 2014: Introduction of ARIADNE, distribution of flyers, DAI	o	35
Scientific symposium at Deva regional county museum, Romania, 11-12 June 2014: presentation of ArheoVest work in ARIADNE	o	120
Colloque Patrimoine et Humanities numeriques, Grenoble, France, 10-12 June 2014: Presentation of ARIADNE to scholars and research students, MIBAC-ICCU	o	30
Meeting with CENIEH, Rome, Italy, 10 June 2014: Presentation of ARIADNE and discussion of collaboration opportunities, PIN	●	5
Meeting with EAGLE project / steering committee members, Rome, Italy, 4 June 2014: Presentation of ARIADNE and discussion of collaboration opportunities, PIN and CYI-STARC	●	10
13th Meeting of the Member States Expert Group on Digitisation, Luxembourg, 2-4 June 2014: Representatives of the 28 Member States and officers of the European Commission, DG Connect participated; presentation and networking for ARIADNE, MiBAC-ICCU	o	45
53rd National Archaeological Conference, Sandanski, Bulgaria, 28-31 May 2014: Presentation about the development of the Archaeological Map of Bulgaria and ARIADNE, Prof. Georgi Nekhrizov, NIAM-BAS	o	100
RCIS 2014, Marrakech, Morocco, 28-30 May 2014: Presentation “An ISO/IEC 24744-Derived Modelling Language for Discourse Analysis”, CSIC-Incipit	o	50
Mapping existing datasets to CIDOC-CRM - PIN, Prato, Italy, ARIADNE summer school/transnational access, 26-30 May 2014	⌂	3
18th Central European Seminar on Computer Graphics, Smolenice, Slovakia, 25-27 May 2014: CESCG brings together young researchers from different countries to present and discuss projects and progress in the application of computer graphics, students from 11 institutions participated; invited talk on visual media services developed within ARIADNE, R. Scopigno, CNR-ISTI	o	150
Symposium “New Approaches to the Temple of Zeus at Olympia”, University ELTE, Budapest, Hungary, 8-10 May 2014: Presentation “Virtual Environments and Technological Solutions for an Enriched Viewing of Historical and Archaeological Contexts”, CNR-ISTI	o	60

Meeting of Danish Humanities Research Infrastructures, Aarhus, Denmark, 6 May 2014: Presentation of ARIADNE and discussion of collaboration opportunities with RI managers, PIN	●	30
IPERION-CH, CHARISMA partnership and other European institutions, Rome, Italy, 28 April 2014: Presentation of ARIADNE, discussion of collaboration opportunities, PIN	●	60
CAA 2014, Paris, France, 25 April 2014: Session “Modelling the Archaeological Process”, CSIC-Incipit (chairs: C. Gonzalez-Perez & P. Martín-Rodilla), presentations by Athena-DCU (C. Dallas) and Inrap (V. Vachon)	●	40
CAA 2014, Paris, France, 25 April 2014: Session “Towards a History of Archaeological Computing”, presentation “The Development of Data Sharing and Open Data in Archaeology”, J. Richards, ADS	O	25
CAA 2014, Paris, France, 24 April 2014: Session “Ontologies and Standards for improving Interoperability of Archaeological Data: From Models towards practical Experiences in various Contexts”, 3 presentations by ARIADNE partners, CSIC-Incipit, KNAW-DANS, USW	O	50
CAA 2014, Paris, France, 23 April 2014: Session “GIS, a new trowel for archaeologists? The challenges of using GIS in preventive archaeology”, presentations by Discovery & Inrap and MNM-NOK	O	30
CAA 2014, Paris, France:, 23 April 2014: Round table “Virtual archaeology, the first 25 years”, PIN and CYI-STARC (co-moderators)	●	25
CAA 2014, Paris, France, 22 April 2014: Workshop “Hands-on Archaeological Conceptual Modelling 2”, CSIC-Incipit	Δ	20
CAA 2014, Paris, France, 22 April 2014: ARIADNE workshop “Online resources for archaeological research”, introduced archaeological researchers to ARIADNE online data resources (ADS, Arachne [DAI] and Fasti Online [AIAC]; also the digital archive tDAR - The Digital Archaeological Record (USA) gave a presentation	Δ	20
Annual Meeting of the Society for American Archaeology 2014, Austin, Texas, USA, 24 April 2014: Presentation “Finding the context: A European perspective on representing and interpreting spatial data from archaeological fieldwork as Linked Open Data”, ADS, USW and FORTH-ICS	O	60
Association of Archaeology and Ancient History, weekly seminars on archaeology for students and young scholars, Timisoara, Romania, 23 April 2014: Presentation/dissemination of ARIADNE information, ARHEO	O	50
Odyssee Symposium, Dutch National Museum of Antiquities, Leiden, Netherlands, 14 April 2014: Introduced ARIADNE to Dutch archaeological project leaders during the interactive panel discussion, KNAW-DANS	O	50
The Dacians in the Banat Plains: Exhibition on the archaeological activities of Arheovest, Timisoara, Romania, 12 April 2014: Presentation of ARIADNE, ARHEO	O	100
Bridging the Danube - International conference, organised by the American Research Center in Sofia, Timisoara, Romania, 10-11 April 2014 (participants from Poland, Serbia, Romania): Presentation/dissemination of	O	150

ARIADNE information, ARHEO		
Laval Virtual 2014 (Exhibition and conference), Laval, France, 9 April 2014: Invited talk on “Virtual clones for Cultural Heritage applications” at the Digital Heritage Symposium, CNR-ISTI	O	80
Institute for Archaeologists - Annual Conference 2014, Glasgow, UK, 9 April 2014: International Cultural Heritage Practice Group presentation “Navigating Collaborative European Projects in Archaeology”, ADS	O	90
The “Other” School, Timisoara, Romania, 7-9 April 2014: archaeological activities with high school students, incl. discussion about Romanian archaeology in the European context, ARHEO	●	80
Launch of DARIAH-GR, Athens, Greece, 7 April 2014: Presentation of ARIADNE, PIN	O	100
2nd International Conference on Research Infrastructures (ICRI), Athens, Greece, 2 April 2014: Networking and informal presentation of ARIADNE, PIN (c.400 conference participants)	O	20
Meeting with delegation of Chinese Universities, Prato, Italy, 26 March 2014: professors from Chinese and Italian Universities and local government officers, presentation of ARIADNE, PIN	●	25
5th Danube Limes Brand Conference, Sofia, Bulgaria, 24-25 March 2014: Danube Limes Brand is a South East Europe - Transnational Cooperation project (10/2012-9/2014), involving partners from Austria, Slovakia, Hungary, Serbia, Bulgaria and Romania; ARIADNE presentation (Prof. G. Nekhrizov & N. Kecheva), NIAM-BAS	O	70
European Archaeological Council - Annual Meeting & Heritage Management Symposium 2014, Amersfoort, Netherlands, 20-21 March 2014: Presentation of ARIADNE, PIN, c.150 event participants	O	70
Workshop at Instituto Andaluz del Patrimonio Historico, Seville, Spain, 17-18 March 2014: Presentation of ARIADNE to director and senior managers of the institute (cooperation agreement), PIN	●	10
CAA-Germany Annual Meeting, Tübingen, Germany, 14-15 February 2014: Presentation/dissemination of ARIADNE information, DAI	O	120
Public lectures / introducing citizens to the results of the on-going excavations in the center of Timisoara within a European perspective, Timișoara, Romania, 12 February 2014, ARHEO	●	120
Bundesamt für Kartografie und Geodäsie (Federal Agency for Cartography and Geodesy): “Gewusst Wo!“ (Know where!), Frankfurt, Germany, 13 February 2014: Event on geographical data, ARIADNE introduction, distribution of flyers, DAI	O	60
Italian national information day on research infrastructures, Pisa, Italy, 6 February 2014: Presentation of ARIADNE in the framework of SSH infrastructures and networking with projects, PIN (c.250 event participants)	O	130
Africa-EU Workshop on the Fight Against Illegal Trafficking of Cultural Goods, Casablanca, Marocco, 20-22 January 2014: ARIADNE presentation, DAI	O	90

DAI IT Days, Berlin, Germany, 20-22 January 2014: ARIADNE presentation, DAI	●	30
DCH-RP - Digital Cultural Heritage Roadmap for Preservation meeting, Catania, Italy, 21 January 2014: Presentation of ARIADNE, PIN	O	40
Archaeological Institute of America, Annual Meeting, Chicago, USA, 2-4 January 2014: Highlighting ARIADNE in the context of the AIA award to Fasti Online for outstanding work in digital archaeology (c.300 present at the awards ceremony).	O	300
Archaeological Institute of America, Annual Meeting, Chicago, USA, 4 January 2014: Meetings to establish or advance cooperation with Open Context (digital archive), tDAR (digital archive), Ancient World Mapping Center (University of North Carolina) and Digital Atlas of Roman and Medieval Civilizations (Harvard University); AIAC	●	7
2013		
NCVPRIPG 2013 - National Conference on Computer Vision, Pattern Recognition, Image Processing and Graphics, Jodhpur, India, 19-21 December 2013: Keynote “High-fidelity 3D models for Cultural Heritage”, incl. service development within ARIADNE, R. Scopigno, CNR-ISTI	O	240
Seminar on Trends, Developments and Knowledge in Archaeological Archiving, Faculty of Archaeology, Ljubljana, Slovenia, 13 December 2013: Presentations on archaeological data management by Valentijn Gilissen, KNAW-DANS	O	40
Pelagios Gazetteer Meeting, Berlin, Germany, 11 December 2013: Presentation of ARIADNE with a focus on CIDOC-CRM extensions, DAI and FORTH-ICS	O	15
Workshop at The British Museum, London, UK, 4 December 2013: Presentation of ARIADNE, PIN and CYI-STARC	O	10
CAA Konferensen, Lund, Sweden, 2-4 December 2013: Keynote / presentation of ARIADNE, S. Pescarin, CNR-ITABC	O	60
Seminar on Linked Open Data, Rome, 29 November 2013: Presentation of ARIADNE work on metadata, PIN	O	25
Research on cultural-historical heritage: provocations and prospects - Second PhD student conference, Sofia, Bulgaria, 29 November 2013: Presentation about the development of AIS-AKB and ARIADNE, Prof. G. Nekhrizov, NIAM-BAS	O	40
Archaeology and the Public Conference, Nečtiny, Czech Republic, 20-22 November 2013: Presentation “Map of aerial archaeological sites” and ARIADNE, ARUP-CAS	O	50
Facing the Future: European Research Infrastructure for the Humanities and Social Sciences conference, organized by the Social and Cultural Innovation Strategy Working Group of ESFRI and the German Federal Ministry of Education and Research, and hosted by the European Federation of Academies of Sciences and Humanities (ALLEA) and the German Data Forum (RatSWD), Berlin, Germany, 21-22 November 2013: Presentation “The ARIADNE approach to digital cultural heritage”, PIN	O	90

MTSR 2013 - 7th International Conference on Metadata and Semantics Research, Thessaloniki, Greece, 19-22 November 2013: Special Track on Metadata & Semantics for Cultural Collections & Applications, presentations by Athena-DCU and USW	O	50
Digital Humanities in Austria - DARIAH AT workshop, Austrian Centre for Digital Humanities at the University of Graz, Austria, 20 November 2013: Presentation of ARIADNE, OEAW	O	60
CHNT 2013 - 18th International Conference on Cultural Heritage and New Technologies, Vienna, Austria, 11-13 November 2013: ARIADNE Session "Infrastructures and services for sharing of archaeological documentation" organised & chaired by SRFG and OEAW, 14 presentations incl. by Athena-DCU, ADS, CNR-ISTI, DISC, FORTH-ICS, KNAW-DANS, OEAW+SRFG, SND, USW	●	40
Meeting PIN-ICCU-ICCD, Rome, 29 October 2013: Presentation of ARIADNE to potential associated partners, PIN	●	10
Digital Heritage International Congress 2013, Marseille, France, 28 October - 2 November 2013: Presentation "A computer-assisted constraint-based system for assembling fragmented objects", CNR-ISTI	O	120
CIDOC-CRM SIG meeting, Heraklion, Greece, 22 October 2013: organised by FORTH-ICS, presentation of CRMarchaeo (part of the ARIADNE Global Model), FORTH-ICS and PIN	●	20
Heritage Council Workshop - Addressing digital heritage data in Ireland, Kilkenny, Ireland, 21 October 2013): Presentation/dissemination of ARIADNE information, Discovery	O	25
DASISH - Data Service Infrastructure for the Social Sciences and Humanities workshop, Gothenburg, Sweden, 4-5 October 2013: coordination meeting of infrastructures and projects active in the social sciences (CESSDA, DwB, ESS, InGRID, SHARE) and humanities (ADRIADNE, CENDARI, CHARISMA, CLARIN, DARIAH, EHRI); contributions by PIN	O	27
TPDL 2013 - 17th International Conference on Theory and Practice of Digital Libraries, Valetta, Malta, 26 September 2013: CRMEX workshop co-org. by PIN; presentations "Quality management of 3D cultural heritage replicas with CIDOC-CRM", "European standards for the documentation of historic buildings and their relationship with CIDOC-CRM", "Mapping ICCD Archaeological Data to CIDOC-CRM: the RA Schema", PIN and Athena-DCU	●	30
AARG 2013 - Aerial Archaeology Research Group, Annual Conference, Amersfoort, Netherlands, 26-28 September 2013: Presentations "From find to structure" and "Integrating ALS, aerial prospection and ground-based survey into the study of visible and hidden components of post-medieval military open landscapes", ARUP-CAS	O	90
Conference of the Stichting Infrastructuur Kwaliteitsborging Bodembeheer (Foundation Infrastructure for Quality Assurance of Soil Management), Zeist, Netherlands, 25 September 2013: Lecture on the protocol for uniform data exchange for Dutch archaeologists, KNAW-DANS	O	25
ArcLand meeting 2013, Amersfoort, Netherlands, 24-25 September 2013: Presentation/dissemination of ARIADNE material, ARUP-CAS and Discovery	O	30

Kick Off Event of DFG project "OpenInfRA", Cottbus, Germany, 20 September 2013: ARIADNE presentation to potential new partners, DAI	o	10
International Summer School "UAVs applied to Cultural Heritage and Archaeology", Certosa, Pontignano, Italy, 20-26 September 2013: Presentation/dissemination of ARIADNE materials, CNR-ITABC	Δ	30
3D PITOTI Workshop, Weimar, 17 September 2013: Presentation/ dissemination of ARIADNE information, DAI	o	30
DARIAH VCC meeting, Copenhagen, 6 September 2013: ARIADNE update presentation, PIN	o	50
EAA 2013 - 19th Annual Meeting of the European Association of Archaeologists, Pilsen, Czech Republic, 5 September 2013: Session "New digital developments in heritage management and research", organised by ADS, Archaeolingua and PIN, 15 presentation, six by ARIADNE partners (ADS, CSIC-Incipit, CyI-STARC, FORTH-ICS, PIN and USW)	●	70
EAA 2013 - 19th Annual Meeting of the European Association of Archaeologists, Pilsen, Czech Republic, 4-8 September 2013: Session "Towards a real representation and interpretation of spatio-temporal data in Archaeological Record", presentation "An ontological spatio-temporal refinement for the CIDOC CRM and GIS standards", FORTH-ICS	o	20
EAA 2013: Pilsen, Czech Republic, 4 September 2013: ARIADNE workshop "Data Management Planning and Online Resources for Archaeology"; centred on strategies for effective data management and planning (ADS, SRFG) and online data resources available to researchers through ARIADNE (ADS, DAI [Arachne], AIAC [Fasti Online], KNAW-Odyssee [E-Depot] and SND [digital archive])	Δ	25
iPRES 2013 - International Conference on Preservation of Digital Objects, co-located with Dublin Core 2013, Lisbon, Portugal, 3-5 September 2013. Presentation/dissemination of information on ARIADNE, Athena-DCU	o	50
JCDL 2013 - ACM/IEEE Joint Conference on Digital Libraries, Indianapolis, Indiana, USA, 22-26 July 2013: Presentation/dissemination of information on ARIADNE, Athena-DCU	o	50
Digital Heritage 2013: Interfaces with the Past, University of York, UK, 6 July 2013: ARIADNE poster, ADS and Discovery (120 total participants)	o	60
Colloquium: Hessian Department of Archaeology, Marburg, 5 July 2013: Presentation/dissemination of ARIADNE information, DAI	o	60
Cultural Heritage Creative Tools and Archives workshop (CHCTA), National Museum of Denmark, Copenhagen, Denmark, 26-27 June 2013: Participants included representatives of humanities e-infrastructures ARIADNE (J. Richards, ADS), CENDARI, DARIAH, EHRI and other projects, e.g. Europeana Cloud, 3D-ICONS and NeDiMAH (C. Dallas & A. Bernardou, Athena-DCU)	o	34
Opening the Past, MAPPA Conference: Pisa, Italy, 13-15 June 2013: Keynote by J. Richards (ADS) and presentation "Past the Opening: building towards the present, on-going dissemination of Dutch archaeological data as part of the DANS archive", V. Gilissen, KNAW-DANS	o	75

CIDOC-CRM SIG meeting, Stockholm, 3-7 June 2013: Co-organised by FORTH-ICS, presentation on the integration of CRMgeo (part of the ARIADNE Global Model) to the CIDOC-CRM core classes, FORTH-ICS	●	12
10th International Conference on Archaeological Prospection, Austrian Academy of Sciences, Vienna, 29 May - 2 June 2013: ARIADNE poster & hand-out of project information, OEAW-OREA (c.250 participants)	O	125
52nd National Archaeological Conference, Hissar, Bulgaria, 31 May 2013: ARIADNE announced as a part of the development of the AIS-AKB system, Prof. Georgi Nekhrizov, NIAM-BAS	O	100
RCIS 2013, Paris, France, 29-31 May 2013: Presentation “Modelling Temporality and Subjectivity in ConML”, CSIC-Incipit	O	35
Virtual Heritage School on Digital Cultural Heritage, Nicosia, Cyprus, 27-30 May 2013: Presentation of ARIADNE by F. Niccolucci, PIN	O	20
UK & Irish Isotopes Group Workshop, Bristol, UK, 28 May 2013: Presentation on ARIADNE - Scientific data integration/coordination with national initiatives; Discovery	O	30
Verso la conoscenza archeologica condivisa - Terzo Convegno, Il SITAR nella Rete della Ricerca Italiana, Rome, Italy, 23-24 May 2013: Presentation of ARIADNE project by F. Niccolucci, PIN	O	70
18th International Congress of Classical Archaeology, Merida, Spain, 13-17 May 2013 (about 800 participants); ARIADNE presented in the session on International Projects, AIAC	O	50
Sustainable Archaeology, Xi’an, China, 6 May 2013: Presentation “Digital Data in archaeology: long term preservation and access”, J. Richards, ADS	O	40
Mind the Gap - International Seminar, Siena, 22-24 April 2013: Presentation/dissemination of ARIADNE information, DAI	O	60
Symposium Onderzoek Jonge Archeologen, Groningen, Netherlands, 12 April 2013: ARIADNE presented and information handed out to 150 starting/young archaeologists, KNAW-DANS	O	150
ECLAP 2013, 2nd International Conference on Information Technologies for Performing Arts, Media Access and Entertainment, Porto, Portugal, 10 April 2013: ARIADNE presentation: “Validating the Digital Documentation of Cultural Objects”, PIN	O	30
CAA 2013, Perth, Australia, 28 March 2013: Session “Archaeological Information Modelling”, CSIC-Incipit	●	30
CAA 2013, Perth, Australia, 26 March 2013: Presentation “Expressing Temporal and Subjective Information about Archaeological, Entities”, CSIC-Incipit	O	50
CAA 2013, Perth, Australia, 25 March 2013: Workshop “Hands-on Archaeological Conceptual Modelling (HACMod)”, C. Gonzalez-Perez of ARIADNE partner CSIC-Incipit (Spain) and Charlotte Hug of Université de Paris 1 Panthéon-Sorbonne	Δ	15
CAA 2013, Perth, Australia, 25-28 March 2013: ARIADNE project poster, ADS and Discovery (350 total participants)	O	60

Arheologija v letu 2013 - dediščina za javnost (Archaeology in 2013 - Heritage for the Public), Ljubljana, Slovenia, 22 March 2013: Symposium on the progress of archaeological research in Slovenia. Presentation of ARIADNE by B. Štular, ZRC-SAZU	●	32
Corpus Signorum Imperii Romani (CSIR) workshop, DAI Rome, 18 February 2013: Workshop with national heads of the CSIR to create a unified digital dataset of sculpture and potential inclusion in ARIADNE, AIAC and DAI	O	15
Total		**13,322**

9 Annex D: Demonstrators

This Annex documents the demonstrators of innovative capabilities enabled by ARIADNE services/ tools, models, vocabularies and datasets that are summarised in *Section 4.7.3*.

D1 - Vocabulary Mapping Demonstrator

Brief description:	Mapping of five subject vocabularies of ARIADNE data providers to the Art & Architecture Thesaurus (AAT) as a central semantic hub, employing vocabulary mapping tools developed in the project. Exploratory pilot involving cross-search over archaeological datasets from different countries with semantic expansion across the vocabularies in different languages.
Innovative capability:	Mappings of local vocabularies to a large, multi-lingual and widely used vocabulary can provide a useful mediation hub for cross-searching metadata of distributed digital resources. A search on a concept originating from any one vocabulary can utilize the mediating structure to route through to concepts from other vocabularies (which may be expressed in different languages) and retrieve the identified data records.
Target user group/s:	Subject experts, data managers and integrators
Methods/services/ tools:	Mapping tools: online interactive Vocabulary Matching Tool and spreadsheet-based tool developed by USW (the tools are described in *Section 4.6.4*)
Data resources & vocabularies:	Terms of five subject vocabularies employed by ARIADNE data providers were mapped to the AAT and the semantic linkage used for retrieval experiments. The vocabularies are: a flat list of monument types employed in Fasti Online (in English), terminology for types of archaeological sites owned by MiBAC-ICCU (in Italian), Archeologische complextypen of the Rijksdienst Cultureel Erfgoed (in Dutch, employed by DANS), terms of DAI's archaeological dictionary (in German), and Historic England's Thesaurus of Monument Types (in English, employed by ADS).
Demonstrator:	ARIADNE data providers employ multiple, partly overlapping local vocabularies with no formal semantic links existing between them. As there is no scalable approach for mapping between concepts in any more than three vocabularies a spine structure needs to be employed. In ARIADNE the Art & Architecture Thesaurus (AAT) of the Getty Research Institute (available as Linked Open Data in SKOS)[250] has been selected to provide the central hub to which data providers have to map the terms of the vocabularies which they use for describing their resources. Thus partners have to produce SKOS mapping relationships such as broadMatch or closeMatch between their vocabulary terms and the AAT concepts. For this work USW developed tools which enable subject experts to produce the mapping and output the SKOS mapping relationships in JSON format. The application of the tools and the "spine"-based mapping approach have been tested and evaluated in an exploratory pilot. The study demonstrated advantages of the approach by performing mediated cross-search over archaeological datasets from different countries with semantic expansion

[250] Getty Vocabularies as Linked Open Data, http://www.getty.edu/research/tools/vocabularies/lod/index.html

	across the multilingual vocabularies.
Partners involved:	USW, contributions by AIAC, DAI, DANS and MiBAC-ICCU
Documentation:	Binding & Tudhope 2016; ARIADNE 2017g (D15.3); see also *Section 4.6.4.*

D2 - Coins Demonstrator

Brief description:	The pilot application demonstrated the item-level integration process of information about coins from five datasets based on the extended CIDOC-CRM and domain-specific vocabulary (AAT, Nomisma).
Innovative capability:	The coins demonstrator confirmed that datasets of different origin, language, property, and of heterogeneous information can be successfully integrated by relying on the CIDOC-CRM. The relative homogeneity of the coin class of objects has made the mapping and conversion work relatively easy. But validity of the methodological approach can be assumed for any type of archaeological object.
Target user group/s:	Developers of CIDOC-CRM based services and data integrators
Methods/services/ tools:	Mapping Memory Manager - 3M (see *Section 4.6.2*); blazegraph RDF graph database
Data resources & vocabularies:	The following datasets have been used in the demonstrator: ○ dFMRÖ - Digitale Fundmünzen der Römischen Zeit in Österreich (Digital Coin-finds of the Roman Period in Austria), online MySQL database – ÖAW Numismatic Research Group; ○ MuseiD-Italia documentation of several coins collections of Italian museums integrated in CulturaItalia – MiBAC-ICCU; ○ A subset of numismatics records (1670) from the Fitzwilliam Museum (Cambridge) database prepared in the COINS project (COINS - Combat On-line Illegal Numismatic Sales, 2007-2009, coordinated by PIN; see Jarrett *et al*. 2011) ○ Coins data records (630) from the Soprintendenza Archeologica di Roma (SAR) database – prepared in the COINS project; ○ Documentation of coin finds (517) in the iDAI.field research database of the Pergamon project, with detailed information about the archaeological context – DAI. ○ Information extracted with Natural Language Processing (NLP) from reports about coins (from Heslington East Excavation Archive, UK). Vocabularies: CIDOC-CRM (incl. CRMdig extension and a small coin-specific extension modelling categorical information), Art & Architecture Thesaurus, Nomisma ontology (numismatics vocabularies)[251]
Demonstrator:	The pilot application demonstrated the process of item-level integration of the diverse coin datasets in an environment where users can effectively query and receive combined results coming from the different datasets. To enable such a search environment four of the datasets were mapped with FORTH-ICS' Mapping Memory Manager (3M) to the CIDOC-CRM (and extensions) and

[251] Nomisma ontology, http://nomisma.org/ontology

	transformed to RDF format. The MuseiD-Italia data was already in CIDOC-CRM RDF form, and the data extracted with NLP from reports were mapped to CIDOC-CRM in the extraction and semantic annotation process. In addition mapping of terms in dataset records to the Art & Architecture Thesaurus (AAT) and Nomisma ontology (both available as Linked Data) was necessary to enable integrated searching of the coins information. The pilot application employs the Blazegraph RDF graph database[252] and the user interface is based on the Metaphacts platform[253]. The platform implements the Fundamental Categories and Relationships for intuitive querying CIDOC-CRM based repositories, described in Tzompanaki & Doerr (2012). Users can formulate queries by selecting from six basic categories and the relations between them without the need to be familiar with the underlying schema. The results of the queries are coming from the different datasets, and it is possible to refine the search with a facet view.
Partners involved:	FORTH-ICS (lead), CNR, DAI, ICCU, ÖAW, PIN
Documentation:	Felicetti, Gerth *et al*. 2016; ARIADNE 2016e (D4.6)

D3 - Sculptures Demonstrator

Brief description:	DAI produced and explored a dataset of semantic data from five different databases based on the CIDOC-CRM and extensions for describing scientific data acquisition and archaeological excavation processes. Furthermore the demonstrator used a bibliographic reference model (FRBRoo) and basic geographic references. DAI developed a prototypical implementation of the different standards for archaeological research regarding time, space, actors, literature and other entities covered by domain-specific vocabulary. The data of the demonstrator is stored in a semantic database (triple store) to perform archaeologically relevant SPARQL queries on the data to showcase the possibilities of the approach.
Innovative capability:	The approach demonstrated the advantages of the extended CIDOC-CRM for research as queries to answer archaeological questions can be run over various integrated datasets. As FRBR and CIDOC-CRM are aligned it could also show great advantages for searching related research literature. The approach allows the user to get literature hits by applying queries which go far beyond the query possibilities of modern literature software with thesauri and free text search.
Target user group/s:	Developers of CIDOC-CRM based services and data integrators
Methods/services/ tools:	Mapping Memory Manager (3M), blazegraph RDF graph database, Arachne OAI-PMH interface, Agora XML interface, British Museum SPARQL endpoint
Data resources & vocabularies:	The following datasets have been used in the demonstrator: ○ German Archaeological Institute: Arachne[254] extracts and data from the iDAI.field instance of the Chimtou project[255],

[252] Blazegraph, https://www.blazegraph.com

[253] Metaphacts, http://www.metaphacts.com

[254] Arachne, the central object database of the German Archaeological Institute and the Archaeological Institute of the University of Cologne, http://arachne.uni-koeln.de

	○ British Museum Linked Open Data[256], ○ Stone Quarries Database of the Oxford Roman Economy Project[257], ○ Athenian Agora Excavation data from the American School of Classical Studies in Athens[258]. Vocabularies: Extended CIDOC-CRM (incl. CRMarchaeo and CRMsci), the object-oriented version of Functional Requirements for Bibliographic Records (FRBRoo)[259] for describing bibliographical records and the Basic Geo vocabulary[260] for simple geometry description.
Demonstrator:	The pilot application presents a case of integration of various different datasets with different origins (museum catalogue, object database, excavation database, research results). The data resources are provided with different services and interfaces and therefore require a novel strategy for integration, based on CIDOC-CRM. The data of the British Museum could be accessed directly via its SPARQL endpoints and integrated by using a SPARQL federated query; the British Museum has the data already organised based on CIDOC-CRM. Arachne's data could be exported via an OAI-PMH interface, which provides RDF/XML using CIDOC-CRM. The other data exports were transformed to XML and imported into FORTH-ICS' Mapping Memory Manager. The 3M editor was used to describe the datasets with CIDOC-CRM and transform the data into RDF format, which could then be imported into the Blazegraph triple store along with Arachne's triples. To enable a unified search environment for all datasets it was necessary to harmonize differing CIDOC-CRM mappings. Furthermore the data was enriched with various Linked Open Data so that the objects' attributes use the same standardised terminology: Wikidata for actors, Getty AAT and Wikidata for archaeological terminology, Zenon for literature and iDAI.gazetteer for places. The search interface has been implemented with Metaphacts on top of the Blazegraph triple store and allows accessing the data in a wiki system. An object-centric and a sites-based view into the web of archaeological Linked Data have been explored. The research questions in the object-centric view concerned comparable objects by applying the same parameters. For example one object-centric query was about a fragmentary head of a Satyr that was found in Chimtou. The sites-based view concerned quarries, for example quarries where white marble was produced. Here search questions were about all possible sculptures from a specific quarry (Pentelli), and literature that describes objects which are made out of the marble of that quarry.

[255] Deutsches Archäologisches Institut: Simitthus / Chimtou (Tunesien) Projekt, http://www.dainst.org/projekt/-/project-display/33904

[256] British Museum - Semantic Web Collection Online, http://collection.britishmuseum.org

[257] Oxford Roman Economy Project (Oxford University): Stone Quarries Database http://oxrep.classics.ox.ac.uk/databases/stone_quarries_database/

[258] Agora Excavations, http://agora.ascsa.net

[259] FRBRoo model, v2.1, February 2015, http://www.cidoc-crm.org/frbr_drafts.html

[260] Basic Geo (WGS84 lat/long) Vocabulary, https://www.w3.org/2003/01/geo/

Partners involved:	DAI, employing British Museum Linked Open Data and other freely available data from the Oxford University and the American School of Classical Studies in Athens.
Documentation:	Gerth *et al*. 2016a/b; ARIADNE 2016e (D4.6)

D4 - Wooden Material Demonstrator

Brief description:	The demonstrator investigated semantic integration and cross-searching of extracts from archaeological datasets and data derived from applying NLP information extraction techniques to the textual content of grey literature reports. The datasets and reports concerned wooden material, including from shipwrecks, with a focus on indications of types of wooden material, samples taken, wooden objects with dating from dendrochronological analysis, etc. The datasets and reports were in different languages (English, Dutch and Swedish). The CIDOC CRM and Getty AAT were used to connect the extracted dataset elements and NLP entities, which include Object, Sample, Material, Place (in some cases), date ranges. The dataset and textual extracts were expressed in RDF (Linked Data) which allowed cross-search of the multi-lingual information.
Innovative capability:	The CRM/AAT Linked Data case study demonstrated the feasibility of connecting information extracted from datasets and grey literature reports in different languages and semantic cross-searching of the integrated information. The demonstrator featured an innovative Web application which hides the complexity of the underlying semantic framework from the user and allows querying and browsing the information without expertise in SPARQL[261]; this represents an essential move towards more intuitive user interfaces for searching RDF datasets than the usual SPARQL endpoint.
Target user group/s:	Developers of CIDOC-CRM based services and data integrators; developers of thesaurus-based services
Methods/services/ tools:	OpenRefine[262] for data cleaning; GATE[263] for NLP; USW's STELETO[264] mapping, extraction and conversion tool for tabular data (used to convert the data and NLP outcomes to CIDOC-CRM); Virtuoso triple store; browser based SPARQL query builder and user search & browse interface developed by USW
Data resources & vocabularies:	The data resources comprised English and Dutch language archaeological datasets and grey literature reports, together with Swedish reports. ADS provided two shipwreck datasets (Newport Medieval Ship[265], Mystery Wreck Project - Flower of Ugie[266]), and the Dendrochronology and Cruck databases

[261] Client application (query builder) on GitHub, https://github.com/cbinding/ARIADNE-data-integration

[262] OpenRefine, http://openrefine.org

[263] GATE (General Architecture for Text Engineering), https://gate.ac.uk

[264] STELETO, https://github.com/cbinding/STELETO

[265] Newport Medieval Ship. N. Nayling (University of Wales Trinity St David) and T. Jones(Newport Museums and Heritage Service), 2014. Archaeology Data Service, http://dx.doi.org/10.5284/1020898

[266] Mystery Wreck Project (Flower of Ugie). Hampshire and Wight Trust for Maritime Archaeology, 2012. Archaeology Data Service, http://dx.doi.org/10.5284/1011899

	of the Vernacular Architecture Group (UK)[267]. DANS facilitated an extract from the database of the international Digital Collaboratory for Cultural Dendro-chronology (DCCD)[268]. USW provided information extracted from 25 grey literature reports written in Dutch, English and Swedish. Vocabularies: CIDOC-CRM, Getty AAT, other dataset vocabularies used by ADS, DANS and SND (mapped to AAT).
Demonstrator:	The research demonstrator allows cross-searching the integrated data with the Web application demonstrator. The user can explore the data with a standard internet browser employing a set of interactive controls. It is possible to search across all datasets (the default) or select a dataset to search individually. The demonstrator can perform semantically structured queries, free-text queries, or a combination of both. Drop-down lists of all datasets, AAT materials and AAT object types used in the data are populated at startup, and a dual slider control is initialized to represent the minimum and maximum years for any object production dates present in the data. This provides useful selectable options to assist query formulation. Hierarchical expansion has been implemented over the semantic structure of the Getty AAT and results from narrower concepts are included when available. A semantic connection between AAT hierarchies allows the scientific names for trees to be taken into account.
Partners involved:	The work was undertaken by USW on the technical side, in collaboration with DANS and SND as regards Dutch and Swedish archaeological datasets, reports and vocabularies.
Documentation:	ARIADNE 2017g (D15.3); Data integration case study - client application, https://github.com/cbinding/ARIADNE-data-integration

D5 - Animal Remains Demonstrator

Brief description:	DAI produced and explored a demonstrator which integrated two datasets of animal remains based on CIDOC-CRM and concepts from vocabulary resources (Encyclopedia of Life, AAT, Wikidata and DAI Zenon). The search application provided useful results for zooarchaeological researchers.
Innovative capability:	Querying zooarchaeological datasets in different languages with regard to particular species (i.e. horses) covered in the datasets, referring to related literature (reports, publications), and generation of statistics such as number of sites/assemblages for selected species.
Target user group/s:	Developers of CIDOC-CRM based services and data integrators
Methods/services/ tools:	Mapping Memory Manager (3M), blazegraph RDF graph database, SPARQL queries of the integrated datasets

[267] Vernacular Architecture Group: Dendrochronology Database, 2000 (updated 2016). Archaeology Data Service, http://dx.doi.org/10.5284/1039454; Cruck database, 2003 (updated 2015). Archaeology Data Service, http://dx.doi.org/10.5284/1031497

[268] Digital Collaboratory for Cultural Dendrochronology (DCCD), http://dendro.dans.knaw.nl

Data resources & vocabularies:	The following datasets have been used in the demonstrator: ○ Ellen Hambleton: A Review of Animal Bone Evidence from Southern England, 2009 (deposited with ADS)[269]; includes information about 108 sites, their distinct bone assemblages (154), and details of identified species based on bone analysis; bibliographic references of the 108 site reports; ○ Benecke N. *et al.*: Holozängeschichte der Tierwelt Europas (deposited with IANUS)[270]; information about animal remains (wild and domestic species) found at over 8500 archaeological sites collected 1995- 1998 from about 4500 publications, including details about the amount of bones separated by species. Vocabularies: CIDOC-CRM, AAT concepts for sites, Encyclopedia of Life taxa names URLs, Wikidata for object measurements, DAI Zenon for bibliographic references.
Demonstrator:	To allow integration and cross-querying of the large datasets in different languages (English, German) basic elements and relations were modelled in CIDOC-CRM. Species names were alignment based on Encyclopedia of Life (EOL) taxa name URLs; as the EOL classification tree is not available in Linked Data format the terms used were described in RDF/XML. Furthermore AAT concepts were used for sites and the DAI Zenon database for documents identifiers; in addition Wikidata was used for object measurement. The integration of the datasets allowed querying the different datasets based on a common aggregated repository which delivers search results from the different datasets. For example, a species-centric query can show all sites with reported bone assemblages that contained horse remains. For a researcher interested in the distribution of a species the literature references could be a welcome starting point. Based on SPARQL queries over the mapped datasets the application also allows generation of statistics, i.e. number of sites/assemblages for selected species.
Partners involved:	DAI (demonstrator), DAI-IANUS and ADS as data providers
Documentation:	ARIADNE 2016e (D4.6)

D6 - Dutch SIKB 0102 Linked Data demonstrator

Brief description:	User requirements interviews with archaeologists indicated that they are interested in archaeological contexts, which means rich information generated in fieldwork. Particularly interesting would be spatio-temporal patterns between archaeological contexts. In the Netherlands since a few years rich fieldwork information is provided in XML documents which follow the SIKB 0102 protocol of the Stichting Infrastructuur Kwaliteitsborging Bodembeheer (SIKB) / Foundation Infrastructure for Quality Assurance of Soil Management[271]. The protocol specifies which mandatory information about excavations and finds has to be provided for project archives that are

[269] http://dx.doi.org/10.5284/1000102

[270] http://dx.doi.org/10.13149/001.mcus7z-2

[271] Stichting Infrastructuur Kwaliteitsborging Bodembeheer: Protocol 0102 Archeologie, http://sikb.nl/datastandaarden/richtlijnen/protocol-0102

	archived in the E-Depot for Dutch Archaeology (managed by ARIADNE partner Data Archiving and Networked Services - DANS)[272]. The SIKB 0102 XML documents as such cannot be used for semantic integration. Therefore the research group reworked the data model using CIDOC-CRM and CRM-EH, converted thesauri which are being used for the XML documents to SKOS, and developed a tool that allows conversion of the XML documents to RDF. Furthermore a Linked Data infrastructure has been set up and populated with the RDF data of a number of SIKB 0102 based project descriptions.
Innovative capability:	Dutch archaeological institutes and companies are required by law to provide documentation of fieldwork according to the SIKB 0102 protocol. Therefore a tool or service which can convert protocol instances to Linked Data and interlink them would be highly welcome. Such a solution might also fuel the interest of the archaeological community in Linked Data and, consequently, in ARIADNE.
Target user group/s:	Developers of Linked Data services, (Dutch) archaeological community – experienced Linked Data users
Data resources & vocabularies:	73 SIKB 0102 XML documents from the E-Depot for Dutch Archaeology (e.g. documents of the Twello de Schaker excavation). Vocabularies: SIKB archaeological protocol 0102; CIDOC-CRM, including the English Heritage extension (CRM-EH); Archeologisch Basisregister (ABR) thesauri.
Methods/services/ tools:	SIKB 0102 archaeological protocol Linked Data translation[273] MINoS Data Mining pipeline[274]
Pilot/demonstrator:	The research group developed a Linked Data version of the SIKB 0102 protocol (called: pakbon-ld). This version incorporates the set of archaeological concepts and properties of the protocol, but restructured and expanded to exploit the graph structure of the Linked Data[275]. The version has been modelled in CIDOC-CRM, including the English Heritage extension (CRM-EH) which contains archaeology-specific concepts and relations. Moreover Archeologisch Basisregister (ABR) thesauri (http://abr.erfgoedthesaurus.nl) of the Rijksdienst Cultureel Erfgoed have been prepared for use in the transformation of SIKB 0102 XML documents to Pakbon Linked Data. Once these foundations were completed, a tool for automatic conversion of SIKB 0102 XML documents to RDF has been developed; the tool supports entity alignment, fuzzy reconciliation, and semantic enrichment. With the tool documents from the E-Depot for Dutch Archaeology have been translated and stored in a graph database together with the CIDOC-CRM, CRM-EH and ABR vocabularies. Furthermore the research team developed a data mining pipeline MINoS (MINing on Semantics) to identify patterns in the

[272] E-depot for Dutch Archaeology, http://www.edna.nl

[273] Wilcke, X. (VU Amsterdam): Linked Data translation of the SIKB archaeological protocol 0102 (aka Pakbon), https://github.com/wxwilcke/pakbon-ld

[274] Wilcke, X. (VU Amsterdam): MINing On Semantics - a Data Mining pipeline for the Semantic Web, https://github.com/wxwilcke/MINOS

[275] Wilcke, X. (VU Amsterdam): Dutch Linked Archaeological Data Cloud, http://pakbon-ld.spider.d2s.labs.vu.nl/home

	Linked Data which support the generation of archaeological hypothesis. The results confirmed a strong dependence of the usefulness of pattern mining for hypothesis generation on the granularity of knowledge embodied in datasets of Linked Data. For archaeologically relevant results fine-grained semantic data is necessary, i.e. sufficient complexity of the structural features (i.e. ontologies) as well as specific information, ideally including literal and numerical values. Linked Data that fulfils these criteria may allow providing relevant results for archaeologists. Among the re-useable results of the demonstrator are the available tools: SIKB 0102 protocol translation to Linked Data, MINoS Linked Data mining pipeline.
Partners involved:	Leiden University and Free University Amsterdam
Documentation:	ARIADNE 2015c (D16.1), ARIADNE 2017h (D16.3), and referenced webpages

D7 - Online NLP service for automatic metadata extraction from research reports

Brief description:	Un-published reports of fieldwork, specialist analysis and other "grey literature" are important but traditionally difficult to access resources in archaeology. There is often little or no metadata available which impedes effective discovery of this literature. Therefore an automatic metadata extraction web application has been developed which identifies and classifies named entities within the archaeological reports. The results are being used to generate or enrich resource discovery metadata for the reports. The web application is being used for the ADS Grey Literature Library, but may be adapted and implemented by other repositories for English language documents. In addition to this application a web service API has been created. This API allows external users submit named entity recognition (NER) tasks to an ADS server, which then returns a set of terms, including their category and offsets. The API provides a simple HTML interface. Users can include the results in their existing data management systems to improve data search & retrieval.
Innovative capability:	Automatic generation of rich metadata for archaeological reports uploaded by practitioners to a digital archive, improved discovery of relevant reports
Target user group/s:	Repositories / collections of "grey literature" documents
Methods/services/ tools:	ADS focused on developing an effective NER module for the web application to generate metadata outputs, and concentrated on exploring additional techniques needed to refine these outputs. NLP techniques such as automatic summarisation and text clustering were also explored. These techniques may be used to add additional functions to the web application.
Data resources & vocabularies:	In order to create the NER module for the web application, training data was first required to train the classifiers used. The training data uses annotation to teach the classifier rules that apply to selected concepts. Two sets of training data were used. One was produced by human annotators; the other using a rule-based machine annotator. The training data is simply plain text, with XML style tags around the relevant properties, and offsets of the entities that were recorded. Following the creation of the training data, it needed to be applied to a classifier. A classifier is a machine learning tool that takes data

	items and places them into classes resulting in a statistical model, which is used to extract entities from entered text. Two classifiers were tested, the Linear Support Vector Machine (SVM) Classifier and the Conditional Random Field (CRF) algorithm, to compare the results and see if one performed better than the other, and the CRF classifier was chosen, as it required less computing time to produce results.
Pilot/demonstrator:	The web-based metadata extraction application has been implemented and tested on 30 English language documents. These documents were full-length UK archaeological reports specially selected for this exercise. The reports varied from five to 120 pages in length, with a total of 225,475 words, resulting in over 5000 annotations for the various entities. The Named Entity Recognition (NER) module works successfully and produces correct entities for the classes it has been trained to identify. Archaeological domain experts were asked to read a sample of the documents, and were then shown a list of entities extracted from the documents using the classifiers. They were then asked how relevant the concepts, subjects and locations that had been extracted were to the documents. This evaluation found that the entities extracted from the documents were all terms found in the document. However, there were some erroneous entities (spelling mistakes, pluralisations, punctuation marks) and from an archaeological mindset some terms extracted were considered less important than others. However, from a NLP viewpoint the classifiers successfully 'learned' from the training data. The models built by the classifier using national gazetteers were then directly applied to the unseen data from grey literature reports. As there is currently no Gold Standard for archaeological grey literature, a group of reports from the North Yorkshire region were chosen and manually scored. The gazetteers were especially useful for improving extraction performance, when applied to more unseen corpora. This confirmed there is substantial overlap of information from various corpora within the grey literature. The web application includes an annotation tool which allows users to produce more training data to better train the NER module. This tool means a user can upload a document or text, and then go through the process of annotating the document by selecting appropriate classes. This can be used to produce more training data, and also provides an intuitive interface for users to correct results which can then be used by the training classifier. Documents can be uploaded and processed on a per-file basis or by using batch creation of metadata for multiple files. The quantity of entities extracted by the NER module can be too large to effectively manage. Therefore clustering techniques have been examined and implemented which tidy, group and rank the entities output. The final output of the NLP is being used as discovery metadata in a prototype implementation. Also a module has been developed to export the selected metadata in a variety of formats. The metadata extraction application is being used for the ADS Grey Literature Library, but other information management systems may build on it (the code can be provided to other developers). To support external use of the application a web service API has been implemented. The API allows external users submit NER tasks to an ADS server, which then returns a set of terms,

	including their category and offsets. The API provides a simple HTML interface. Users can include the results in their existing data management systems to improve data search & retrieval.
Partners involved:	Archaeology Data Service (ADS)
Documentation:	ARIADNE 2015d (D16.2), ARIADNE 2017i (D16.4) Metadata extraction application: is being used for the ADS Grey Literature Library, but may be adapted and implemented by other repositories for English language documents (the code can be provided to other developers) Online NER service API interface: http://ads.ac.uk/nlp/demo.jsf

D8 - NLP-based identification of research methods and processes

Brief description:	Archaeologists usually describe the research methodologies they applied in a section of the excavation or survey report. NLP techniques have been employed to identify and extract description of activities/methods and relations between them.
Innovative capability:	Detection of described research activities and underlying process models could facilitate knowledge sharing, comparison of approaches and, possibly, improve the team-based research work. Instead of carrying out this work by hand, now it can be partially automated.
Target user group/s:	Developers of tools/services
Methods/services/ tools:	TextProcessMiner tool using verb semantics for activities mining and a rule-based approach for activity relationships detection. Developed in Python employing and evaluating the advantages of different NLP libraries for the purpose (e.g. NLTK[276]).
Data resources & vocabularies:	Archaeological reports / publications Vocabularies: For building a dictionary of verbs for the text mining VerbNet and WordNet have been employed[277].
Demonstrator:	The innovative approach has been demonstrated and evaluated in a case study on the Villa Magna Project[278]. The project surveyed and conducted excavations of a large imperial Roman villa and its estate, and studied the subsequent life of the site, its fortification in late antiquity and the creation of a monastery among the ruins in the 10th century. A report on the excavations in 2009 has been used for the case study (Fentress 2010). The application of the TextProcessMiner identified 34 research activities of which 30 (88%) were correct and suggested a process model that adequately reflected the research process. The archaeological research director confirmed the comprehensiveness of the model and stated that it "flows like the archaeological site investigation process". The director also stated that she would use the model for teaching or for disseminating knowledge to non-specialists, but would not consider it for knowledge sharing with other colleagues or for professional

[276] NLTK - Natural Language Toolkit, http://www.nltk.org

[277] VerbNet, https://verbs.colorado.edu/~mpalmer/projects/verbnet.html; WordNet, https://wordnet.princeton.edu

[278] Villa Magna Project (Fentress L. *et al*. 2006-2010), http://www.villa-magna.org

	process guidance.
Partners involved:	CSIC-Incipit and AIAC in collaboration with researchers/developers of Université Paris 1 Panthéon-Sorbonne / Centre de Recherche en Informatique
Documentation:	Epure *et al*. 2015; Gonzalez-Perez *et al*. 2016; ARIADNE 2017j (D17.1, section 5.2: Archaeological Methodology - CSIC)

D9 - ISO/IEC 24744 based methods component database (CSIC-Incipit)

Brief description:	CSIC-Incipit employed the ISO/IEC 24744 Metamodel for Development Methodologies to formally describe archaeological activities and methods extracted from fieldwork and laboratory reports of ARIADNE partners. An ISO/IEC 24744 compliant database of method component descriptions in XML format has been produced. Furthermore, work is under way to possibly offer the collection through ARIADNE to enable developers building a Methods Component Composer service/application.
Innovative capability:	Capture, formalised description and re-use of methods components of archaeological practices from a shared database, possibly with a methods component composer.
Target user group/s:	Archaeologists
Methods/services/ tools:	TextProcessMiner (NLP tool) ISO/IEC 24744 standard (Metamodel for Development Methodologies) ISO/IEC 24744 compliant database populated with the results from manual and NLP-assisted processing of methodology reports
Data resources & vocabularies:	Archaeological methodology reports; >220 individual method components and multiple associations, each method component also traced back to the source from where it has been “mined”
Demonstrator:	CSIC-Incipit applied a Situational Methods Engineering (SME) approach by which informal methodological knowledge contained in fieldwork and laboratory reports of ARIADNE partners were extracted and formalised as discrete components, stored into a database, and linked to other components. NLP techniques have been used to assist in the information extraction and formalisation process. The resulting repository has allowed obtaining variations of established methodologies to cater for different project situations or combining different methodologies. The researchers propose the development of a toolset for SME in archaeology which would comprise of tools for repository creation, population and usage. Work is under way to possibly offer the methods collection through ARIADNE to enable developers building a Methods Component Composer service/ application.
Partners involved:	CSIC-Incipit (lead), AIAC, ArheoVest, Discovery, MNM-NÖK
Documentation:	Gonzalez-Perez *et al*. 2016; ARIADNE 2017j (D17.1, section 5.2: Archaeo-logical Methodology - CSIC)

D10 - Interactive 3D Web viewer of the ADS digital archive

Brief description:	Implementation of the 3DHOP interactive Web presentation solution for high-resolution 3D models on the digital archive of the Archaeology Data Service.
Innovative capability:	In the past ten years a large number of 3D models have been created for the documentation and reconstruction of cultural heritage. However, the management, accessibility and use of such models on the web for research and dissemination have been far from optimal. 3DHOP provides an effective environment for all kinds of users, including those who are unfamiliar with 3D technologies.
Target user group/s:	Researchers and other users of digital archives providing access to 3D models
Methods/services/ tools:	3DHOP (3D Heritage Online Presenter) is an open source software package for the creation of interactive Web presentations of high-resolution 3D models of cultural heritage objects. 3DHOP provides a series of ready-to-use templates for the presentation and employs multi-resolution encoding for the efficient streaming of the models. The 3D visualisation can also interconnect with other multimedia. Thanks to its modular nature and a declarative-like setup, 3DHOP is easy to learn, configure, and customize at different levels, depending on the programming skills of the user. 3DHOP is written in JavaScript and uses the SpiderGL 3D graphics library, which employs the WebGL subset of HTML5, implementing plugin-free 3D rendering on many web browsers.[279]
Data resources:	High-resolution 3D models deposited in a digital archive
Pilot/demonstrator:	ADS have implemented a 3D viewer for accessing and exploring 3D models deposited in their digital archive. The viewer extends the web-based browsing functionality of the ADS project archives by enabling users to browse 3D geometry directly. The greater ambition is to provide an interactive 3D web-based working environment for the management, visualisation and analysis of archaeological data. This would include different layers of archaeological stratigraphy, e.g. 3D metric reproductions of the excavation process, and the interpretations made by different scholars of the same context.
Partners involved:	ADS and CNR-ISTI
Documentation:	ADS 3D Viewer webpage[280]; Galeazzi 2015; Galeazzi *et al*. 2016

D11 - ARIADNE Visual Media Service – innovative use cases

Brief description:	The ARIADNE Visual Media Service[281] provides a set of productive web-based services that support three types of media: high-resolution images, Reflection Transformation Images (RTI) and 3D models.
Innovative	Enabling more effective publication, visualisation and exploration of high-

[279] SpiderGL, http://spidergl.org ; WebGL (Web Graphics Library), https://en.wikipedia.org/wiki/WebGL

[280] ADS 3D Viewer webpage, http://archaeologydataservice.ac.uk/research/3D_Viewer

[281] ARIADNE Visual Media Service, http://visual.ariadne-infrastructure.eu

capability:	resolution visual media on the Web. Innovative use cases of the service for example are media-rich research publications comprising of the papers and underlying data (evidence) presented as RTI images or 3D models. This is an increasingly pressing need of digital humanities projects, archives and e-journals. Tools and services that enable this are now available.
Target user group/s:	Researchers, digital archives, virtual museums, e-journals
Methods/services/ tools:	The Visual Media Service is based on WebGL, SpiderGL and 3DHOP (3D Heritage Online Presenter); for the 3D service in addition to WebGL also a Javascript implementation of the Nexus multi-resolution framework is being employed[282]. The main platform at the base of the ARIADNE Visual Media Service is 3DHOP, an open source solution developed by CNR-ISTI (Potenziani *et al*. 2015). A content publisher who uses the service is asked only to fill a small form and to upload the raw visual media file; all processing to transform the data in a web-compliant and efficient format is done remotely by a dedicated server. For each media type, automatic conversion to a multi-resolution representation is supported, enabling data compression, progresssive transmission and view-dependent rendering in a web-browser. Content publishers can configure the style of the web page and navigation paradigm. Also additional tools have been made available, for example for creating sections and for taking point-to-point measurements.
Data resources:	Media files of the service users
Demonstrators:	Among the users of the basic 3DHOP service for example is Zamani, the African Cultural Heritage and Landscape Database. Zamani has documented with 3D models cultural heritage sites in different African countries[283]. A research-focused use case of the service is the repository of the German excellence cluster project TOPOI (The Formation and Transformation of Space and Knowledge in Ancient Civilizations)[284]. The research platform has been launched in spring 2016 and serves the publication of citable research data such as high-resolution images and 3D models. This implemented solution confirms the solid status of the open access/source services and tools provided by CNR-ISTI.
Partners involved:	CNR-ISTI (technology provider) External partner/users: Humboldt-Universität zu Berlin, Excellenzcluster TOPOI, Prof. Dr. Gerd Grasshoff (coordinator) and TOPOI researchers TOPOI research platform / repository, http://repository.edition-topoi.org
Documentation:	Technical documentation: ARIADNE 2017d (D13.4)

[282] NEXUS Multiresolution Visualization, http://vcg.isti.cnr.it/nexus/

[283] Zamani Project, http://zamaniproject.org

[284] TOPOI project, http://www.edition-topoi.org

D12 - ARIADNE Landscape Services - innovative use cases

Brief description:	The ARIADNE Landscape Services[285] are productive web-based services that support generation/composing, management and publication of large, multi-resolution 3D interactive terrain datasets (i.e. <20 cm imagery resolution). Users can create interactive containers for online presentation of landscapes, including advanced illumination models, employ rich annotation features for HTML5 multimedia content, and offer access on desktop and mobile browsers.
Innovative capability:	The services enable more effective generation, publication, visualisation and exploration of archaeological and other cultural heritage landscape reconstructions in virtual archaeology projects. The cloud-based approach of the services and task management offer great flexibility in terms of access policies and collaborative online work of professionals in landscape reconstruction projects.
Target user group/s:	Researchers / research projects
Methods/services/ tools:	The Landscape Services build on and leverage open source frameworks and toolkits such as GDAL[286], OpenSceneGraph[287], OSGjs[288], and ownCloud[289]. Data management is performed through a cloud service, allowing fine-grained access control on input/output data, with specific focus on input digital terrain and elevation models (DTMs/DEMs), imagery and shape files. The services offer the user different options to control format, resolution and dissemination segment, and then takes care of multi-resolution, geometry/ texture compression and more. A gallery service allows the producer to control, update or delete projects. The WebGL based front-end[290] for online dissemination provides features such as paged multi-resolution on desktop and mobile browsers for efficient streaming, camera and point-of-view management, multi-texturing and spherical panoramas.
Data resources:	Data of the service users
Demonstrators:	Landscape Services were employed in temporary (short-term) dataset generation and in long-term / permanent publication of 3D landscapes for the creation of interactive model containers online. Among the recent use cases are the Katuns project (Montenegro) and the Valle Calore project (Italy). In the Katuns cultural landscape project the services were employed by the Historical Institute of Montenegro at Podgorica, with support by CNR-ITABC. The Virtual Museum of the Upper Calore Valley is a project on cultural traditions of the Hirpinia region (Campania, Southern Italy). Here a model of the Valle Calore area supports users in exploring a geographic platform with HTML5 annotations including text, images and videos related to the main historical episodes of the area.

[285] ARIADNE landscape services, http://landscape.ariadne-infrastructure.eu

[286] GDAL - Geospatial Data Abstraction Library, http://www.gdal.org

[287] OpenSceneGraph is an open source 3D graphics toolkit, http://www.openscenegraph.com

[288] OSGjs is a WebGL (Web Graphics Library) framework based on OpenSceneGraph concepts, http://osgjs.org

[289] ownCloud, http://www.owncloud.org

[290] VHLab 3D scenes lab: ATON Front-End: http://osiris.itabc.cnr.it/scenebaker/index.php/projects/aton/

	The Virtual Museum allows travelling in time and space, learning about history and culture of the territory, guided by protagonists of a twenty-century history to discover secrets of the Hirpinia landscape.
Partners involved:	CNR-ITABC (service provider) External partner/users: KATUN Project: Historical Institute of Montenegro at Podgorica, Montenegro, http://katun.me Valle Calore project: Province of Avellino and Polo Museale della Campania, Italy, http://www.archeovirtual.it/index.php/valle-calore/
Documentation:	Technical documentation: ARIADNE 2017d (D13.4)

10 References: Organisations, projects and content/data resources

This list of references includes organisations, projects and content/data resources mentioned in the report and a few addition sources on related topics.

10.1 Research (e-)infrastructure organisations and projects

Major organisations & projects (selected, not including domain e-infrastructures):

EGI.eu - International Grid & Cloud Infrastructure for Research, http://www.egi.eu

e-IRG - e-Infrastructures Reflection Group, http://www.e-irg.eu

ESFRI - European Strategy Forum on Research Infrastructures, http://ec.europa.eu/research/esfri/

ESFRI - StR-ESFRI - Support to Reinforce the European Strategy Forum for Research Infrastructures (ESFRI), http://www.esfri.eu

EUDAT - European Data Infrastructure (FP7, 10/2011-9/2014; H2020, 3/2015-2/2018), http://www.eudat.eu

European Commission, DG Research & Innovation, Infrastructures, https://ec.europa.eu/research/infrastructures/

GÉANT - European research and education networking collaboration, http://www.geant.net

OpenAIRE - Open Access Infrastructure for Research in Europe, https://www.openaire.eu

PRACE - Partnership for Advanced Computing in Europe, http://www.prace-project.eu

RAMIRI - Realising and Managing International Research Infrastructures 1+2 projects (11/2008-10/2012), http://www.ramiri.eu

RItrain - Research Infrastructures Training Programme (EU, H2020, 9/2015-8/2019), http://ritrain.eu

Observatories / registries:

E·nventory - The European e-Infrastructures Observatory (FP7-RI, CSA, 2010-2012), http://www.enventory.eu

MERIL - Mapping of the European Research Infrastructure Landscape, http://portal.meril.eu

RICH 2020 - European Network of National Contact Points for Research Infrastructures in Horizon 2020 (formerly EuroRIs-Net), http://www.rich2020.eu

RICH 2020 - Observatory of Research Infrastructures' Network (provides information about Research Infrastructures and RI support projects), http://observatory.rich2020.eu

Repositories / registries:

COAR - Confederation of Open Access Repositories, http://www.coar-repositories.org

OpenDOAR - Directory of Open Access Repositories, http://www.opendoar.org

re3data - Registry of Research Data Repositories, http://www.re3data.org

ROAR - Registry of Open Access Repositories, http://roar.eprints.org

10.2 Archaeology & heritage organisations

Aarhus University, School of Culture and Society, Denmark, http://cas.au.dk/en/

Alexandria Archive Institute (USA, provides the archaeological data publication platform Open Context), http://alexandriaarchive.org

American School of Classical Studies in Athens, Greece, http://ascsa.net

Archaeological Institute of Luxembourg, http://www.ial.be

Archaeological Institute of the Andalusian Heritage, Spain, http://www.iaph.es

Archéologie de la France Informations, France, http://adlfi.revues.org

Archives nationales d'outre-mer, France, http://www.archivesnationales.culture.gouv.fr/anom/en/

Archivio dello Stato Italiano, Italy, http://acs.beniculturali.it

ArkéoTopia, France, http://www.arkeotopia.org

British School at Athens, http://www.bsa.ac.uk

CAA International, http://caa-international.org/about/history/

Centre for Doctoral Training in Science and Engineering in Arts Heritage and Archaeology (SEAHA), UK, http://www.seaha-cdt.ac.uk

Centre National de Recherche en Archéologie – CNRA, Algeria, http://cnra.dz

Centro Nacional de Investigación sobre la Evolución Humana (CENIEH) / National Research Centre on Human Evolution (CENIEH), Burgos, Spain, http://www.cenieh.es/en

Consortium Mémoire des Archéologues et des Sites Archéologiques (MASA), http://masa.hypotheses.org

DGUF - Deutsche Gesellschaft für Ur- und Frühgeschichte e. V., http://www.dguf.de

Digital Antiquity (USA, provides the tDAR digital archive); https://www.digitalantiquity.org

Directorate-General for Cultural Heritage, Lisbon, Portugal, http://www.patrimoniocultural.pt/en/

École française de Rome (section archaeology), Italy, http://www.efrome.it/fr/la-recherche/archeologie.html

English Heritage, UK, http://www.english-heritage.org.uk

European Archaeological Council (EAC), http://european-archaeological-council.org

European Association of Archaeologists (EAA), http://e-a-a.org

Fornleifastofnun Íslands / The Institute of Archaeology, Reykjavík, Iceland, http://www.instarch.is

Forum on Information Standards in Heritage (FISH), UK, http://fishforum.weebly.com

FRANTIQ - Fédération et ressources sur l'Antiquité, l'Institut des sciences humaines et sociales du Centre National de la Recherche Scientifique, http://frantiq.mom.fr

French school in Madrid / Casa di Velasquez (section ancient and mediaeval studies), Spain, https://www.casadevelazquez.org

Heritage Council, Ireland, http://www.heritagecouncil.ie

Heritage Malta (national agency for cultural heritage), Malta, http://heritagemalta.org

ICCROM - International Center for the Study of the Preservation and Restoration of Cultural Property, http://www.iccrom.org

Institut National du Patrimoine, Tunesia, http://www.inp.rnrt.tn

Institute National des Science de l'Archeologie et du Patrimoine – INSAP, Marocco, http://www.minculture.gov.ma/fr/index.php/44-culture-et-recherches/patrimoine/413-institut-national-des-sciences-de-larcheologie-et-du-patrimoine

Institute of Cultural Heritage (IBC), Regione Emilia Romagna, Italy, http://ibc.regione.emilia-romagna.it/en

Israel Antiquities Authority, Israel, http://www.antiquities.org.il

Maison de l'Orient et de la Méditerranée, Université Lyon 2, CNRS, France, http://www.mom.fr

National Institute of Anthropology and History – INAH, Mexico, http://www.inah.gob.mx/en/

Norwegian Directorate for Cultural Heritage, Norway, http://www.riksantikvaren.no/en/

Rijksdienst Cultureel Erfgoed, Netherlands, http://culturalheritageagency.nl/en

Slovak Academy of Sciences, Institute of Archaeology, Slovakia, http://www.sav.sk/?lang=en&charset=ascii&doc=org-ins&institute_no=2

Society for Libyan Studies, London, UK, http://www.societyforlibyanstudies.org

Soprintendenza Speciale per il Colosseo (SSCol), Il Museo Nazionale Romano e l'Area Archeologica di Roma, Italy, http://archeoroma.beniculturali.it/en

Universidad de Jaén, Instituto Universitario de Investigación en Arqueología Ibérica, Spain, http://www.ujaen.es/centros/caai/inicio.html

Università di Siena, Dipartimento di Archeologia e Storia delle Arti, Italy, http://www.archeoarti.unisi.it

University of Oslo, Museum of Cultural History, http://www.khm.uio.no/english/

10.3 Archaeology & heritage projects

3D-ICONS – 3D Digitisation of Icons of European Architectural and Archaeological Heritage (EU, ICT-PSP, 2/2012-1/2015), http://www.3dicons-project.eu

ACCORD - Archaeology Community Co-Production of Research Data (involved citizens in the creation of 3D objects of heritage objects), https://accordproject.wordpress.com

Ancient Lives (crowd sourcing project, transcription of Egyptian papyri), http://ancientlives.org

ARCHES - Archaeological Resources in Cultural Heritage: a European Standard (EU Culture Programme, 6/2012-5/2014), http://archaeologydataservice.ac.uk/arches/

ArcLand - ArchaeoLandscapes Europe (EU, Culture Programme, 9/2010-8/2015, focus: surveying techniques such as aerial photography, satellite imagery, LiDAR and others), http://www.archaeolandscapes.eu

CARARE - Connecting Archaeology and Architecture in Europeana (EU, ICT-PSP, 2/2010-1/2013), http://www.carare.eu

CENDARI - Collaborative European Digital Archive Infrastructure (EU, FP7, 2/2012-1/2016), http://www.cendari.eu

CLARIN - Common Language Resources and Technology Initiative / Infrastructure (ERIC), http://www.clarin.eu

CLAROS - The world of art on the semantic web, http://www.clarosnet.org

COINS - Combat On-line Illegal Numismatic Sales (2007-2009, coordinated by PIN VastLab), http://cordis.europa.eu/project/rcn/85192_en.html

CulturaItalia (MiBACT), http://www.culturaitalia.it

Cultural Heritage Counts for Europe (EU, Culture Programme, 7/2013-6/ 2015), http://blogs.encatc.org/culturalheritagecountsforeurope/

cyberNABO - North Atlantic Cyberinfrastructure Project, http://www.cybernabo.org

DARIAH - Digital Research Infrastructure for the Arts and Humanities (ERIC), https://www.dariah.eu

DARIAH - EGI DARIAH CC (EGI-Engage project, 4/2015-9/2017), https://wiki.egi.eu/wiki/CC-DARIAH

DARIAH - Humanities at Scale (HaS-DARIAH) project (H2020, 9/2015-8/2017), http://www.dariah.eu

DARIAH - Virtual Competency Centres (VCCs): http://dariah.eu/activities.html

DCH-RP - Digital Cultural Heritage Roadmap for Preservation - Open Science Infrastructure for Digital Cultural Heritage in 2020 (FP7, 10/2012-9/2014), http://www.dch-rp.eu

Digital Index of North American Archaeology (DINAA), http://ux.opencontext.org/archaeology-site-data/

DISCO - Discovering the Archaeologists of Europe (EU, Leonardo da Vinci II, 2006-8; Lifelong Learning Programme, 2012-14), http://www.discovering-archaeologists.eu

EAGLE - Europeana Network of Ancient Greek and Latin Epigraphy (EU, ICT-PSP, 4/2013-3/2016), http://www.eagle-network.eu

EHRI - European Holocaust Research Infrastructure (FP7, 10/2010- 3/2015; H2020, 5/2015-4/2019), http://www.ehri-project.eu

E-RIHS - European Research Infrastructure for Heritage Science (ESFRI Roadmap entry 2016, expected preparatory phase 2017-2019), http://www.e-rihs.eu

Europeana Cloud – eCloud (EU, ICT-PSP, 2/2013-1/2016), http://pro.europeana.eu/web/europeana-cloud

Europeana Research - Liberating Cultural Heritage for Use in Research, http://research.europeana.eu

FAIMS - Federated Archaeological Information Management Systems Project (Australia, led by Macquarie University), https://www.fedarch.org

Flow of Ancient Metal Across Eurasia – FLAME (University of Oxford, Research Laboratory for Archaeology and the History of Art, ERC-funded project), http://flame.arch.ox.ac.uk

HeritageToGather (involved citizens in the creation of 3D objects of heritage objects), http://heritagetogether.org

IANUS - Research Data Centre for Archaeology and Classical Studies in Germany (coordinated by the German Archaeological Institute), http://www.ianus-fdz.de

IPERION-CH - Integrated Platform for the European Research Infrastructure on Cultural Heritage, (H2020, 5/2015-4/2019), http://www.iperionch.eu

JPI-Cultural Heritage - Joint Programming Initiative on Cultural Heritage and Global Change (initiative of European ministries and cultural heritage agencies, supported by the FP7 Environment and ERA-Net programmes), http://www.jpi-culturalheritage.eu

LoCloud (EU, ICT-PSP, 3/2013-2/2016), supported small and medium-sized institutions to make digital content available to Europeana, employing cloud services for the data aggregation, http://www.locloud.eu

MicroPasts (crowd sourcing project, transcription of museum object cards which document Bronze Age metal artefacts), http://micropasts.org

NEARCH - New ways of Engaging audiences, Activating societal relations and Renewing practices in Cultural Heritage (EU, Culture Programme, 2013-2018), http://www.nearch.eu

NeDIMAH - Network for Digital Methods in the Arts and Humanities (European Science Foundation, Research Networking Programme, 5/2011-4/2015), http://www.nedimah.eu

Nomisma (collaborative project on linking numismatics data), http://nomisma.org

OpenAIRE - Open Access Infrastructure for Research in Europe (current: OpenAIRE2020, 1/2015-7/2018), http://www.openaire.eu

PARTHENOS - Pooling Activities, Resources and Tools for Heritage E-research Networking, Optimization and Synergies (H2020, 5/2015-4/2019), http://www.parthenos-project.eu

Pelagios (collaboration of over 40 organisations/projects in Europe and the United States for linking content to ancient places based gazetteers), http://commons.pelagios.org

PeriodO - Periods, Organized (University of Texas at Austin), http://perio.do

SENESCHAL - Semantic Enrichment Enabling Sustainability of Archaeological Links (UK, AHRC-funded project, 2013-2014), http://hypermedia.research.southwales.ac.uk/kos/seneschal/

SKOPE - Synthesized Knowledge of Past Environments (Washington State University), online data integration tool, http://www.envirecon.org

UrCrowdsource (crowd sourcing project, transcription of field notes, letters, reports, etc.), http://urcrowdsource.org

10.4 Archaeology & heritage data resources and services

3D-ICONS Ireland (Discovery), http://www.3dicons.ie

AGOnline - Archaeology in Greece Online, http://www.chronique.efa.gr

American School of Classical Studies in Athens, digital collections, http://ascsa.net

ARACHNE - IDAI.objects database (German Archaeological Institute), http://arachne.uni-koeln.de

Archaeobotanical Database of the Czech Republic – CZAD (ARUP-CAS / Institute of Archaeology at the Czech Academy of Sciences), http://www.arup.cas.cz/czad/?l=en

Archaeological Map of Bulgaria (NIAM-BAS): AIS AKB system, http://www.naim-bas.com/akb/

Archaeological Map of the Czech Republic (ARUP-CAS *et al.*), http://www.archeologickamapa.cz

Archaeological Survey of Ireland (National Monuments Service), http://www.archaeology.ie

Archaeology Data Service - ADS (University of York, UK), http://archaeologydataservice.ac.uk

Archéologie de la France Informations (publishes information about archaeological research work conducted in France), http://adlfi.revues.org

Archeozoom (Inrap), http://www.inrap.fr/archeozoom

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ARIADNE - Dataset Catalogue Model (ACDM) support website, http://support.ariadne-infrastructure.eu

ARIADNE - Portal: http://portal.ariadne-infrastructure.eu

ARIADNE - Reference Model (extended CIDOC-CRM), http://www.ariadne-infrastructure.eu/Resources/Ariadne-Reference-Model

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ARKAS – Arheološki kataster Slovenije (ZRC-SAZU), http://arkas.zrc-sazu.si

ArSol - Archives du Sol / Soil Archives (Université de Tours, Laboratoire Archéologie et Territoires, CNRS), http://arsol.univ-tours.fr

Artefacts - Online Encyclopedia of Archaeological Small Finds (Maison de l'Orient et de la Méditerranée, Université Lyon 2, CNRS), http://artefacts.mom.fr

British Museum - Semantic Web Collection Online, http://collection.britishmuseum.org

CHARM - Cultural Heritage Abstract Reference Model (CSIC-Incipit, Spain), http://www.charminfo.org

CIDOC - Conceptual Reference Model (CIDOC-CRM), http://www.cidoc-crm.org

ConML (conceptual modelling language specifically for the humanities and social sciences; CSIC-Incipit, Spain), http://www.conml.org

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DARMC - Digital Atlas of Roman and Medieval Civilizations (Harvard University, USA), http://darmc.harvard.edu/icb/icb.do

dFMRÖ - Digitale Fundmünzen der Römischen Zeit in Österreich / Digital Coin-finds of the Roman Period in Austria (ÖAW, Numismatic Research Group), http://www.oeaw.ac.at/antike/index.php?id=358

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Digital Repository of Ireland, http://dri.ie

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E-depot for Dutch archaeology (part of the DANS-EASY archiving system, KNAW-DANS), http://www.edna.nl

Europeana - The gateway to digital content of archives, libraries and museum across Europe, http://www.europeana.eu

Fasti Online (AIAC, Italy), http://www.fastionline.org

Franzhausen Kokoron database (ÖAW-OREA; information about Late Bronze Age graves and their finds such as bones and pottery), http://epub.oeaw.ac.at/franzhausen-kokoron2/

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Getty Research Institute: Vocabularies (Linked Open Data), http://www.getty.edu/research/tools/vocabularies/lod/index.html

Heritage Data - Linked Data Vocabularies for Cultural Heritage (UK thesauri), http://www.heritagedata.org

OASIS - Online Access to the Index of Archaeological Investigations (UK), http://oasis.ac.uk

Canmore database (Historic Environment Scotland), provides access to information for 300,000 historic places in Scotland), https://www.historicenvironment.scot/archives-and-research/archives-and-collections/canmore-database/

Hungarian National Museum - Archaeology Database, http://archeodatabase.hnm.hu/en

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Irish Stone Axe Project (Discovery Programme), http://www.irishstoneaxeproject.org

Leo Swan Aerial Photography (Discovery), https://lswanaerial.locloudhosting.net

Open ICCD (Istituto Centrale per il Catalogo e la Documentazione, Italy), http://www.catalogo.beniculturali.it/opendata

MAGIS - Mediterranean Archaeology GIS (DePauw University, USA), a database of surveys in the Mediterranean since 1980, http://cgma.depauw.edu/MAGIS

MAPPA (University Pisa, Italy), open data repository, http://mappaproject.arch.unipi.it/?lang=en

Mapping Death (Discovery), http://www.mappingdeathdb.ie

Nomisma (numismatics datasets and ontology), http://nomisma.org

Open Context (Alexandria Archive Institute, USA), archaeological data publication platform, http://opencontext.org

PACTOLS (Peuples, Anthroponymes, Chronologie, Toponymes, Œuvres, Lieux et Sujets), multi-lingual thesaurus, http://pactols.frantiq.fr/opentheso/

PANGAEA - Data Publisher for Earth & Environmental Science (includes over 3200 datasets concerning "archaeology"), http://www.pangaea.de

PeriodO - Periods, Organized (provides a system for publishing cultural periods), http://perio.do

PICO thesaurus (MiBAC-ICCU, Italy), http://purl.org/pico/thesaurus_4.2.0.skos.xml

Pleiades (community-built gazetteer and graph of ancient places), http://pleiades.stoa.org

Propylaeum-DOK (Heidelberg University Library, Germany), https://www.propylaeum.de

SEAD - The Strategic Environmental Archaeology Database (University of Umea), Sweden, http://www.sead.se

SIGEC Web (MiBAC-ICCU), Italian catalogue of heritage objects, http://www.catalogo.beniculturali.it

SITAR - Sistema Informativo Territoriale Archeologico di Roma, http://www.archeositarproject.it

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STARC Repository (Cyprus Institute), contains 2D and 3D archaeological data, http://public.cyi.ac.cy/starcRepo/

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tDAR - The Digital Archaeological Record (Digital Antiquity, USA), digital archive, http://www.tdar.org

TOPOI (The Formation and Transformation of Space and Knowledge in Ancient Civilizations), collections, http://repository.edition-topoi.org

UK_Material_Pool (ÖAW-OREA, information about Late Bronze Age urnfield culture [UK] settlements in Austria), http://www.oeaw.ac.at/praehist/projekte/bronzezeit/ukpool/index.html

WODAN - Archaeological Wood & Charcoal Database (Discovery Programme, Ireland), http://www.wodancharcoal.ie

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