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'*Good data in, good data out*' is a well-known adage, often used to consider the 'precision' of data entry rather than other human activity when inputting information into a database. These could be omissions or errors, but are just as likely to be inconsistencies in data recording. This is especially relevant when thinking about the efficiencies that recorders might make (i.e., to make their work easier) and what this could mean for end users (e.g., researchers). For example, a recorder of an archaeological object might do things differently based on their knowledge or understanding of the value of recording certain types of data (e.g., the various characteristics of the object) and how this information is likely to be used by others. With this in mind, this article will consider the research question of how can advancing Findable, Accessible, Interoperable, Reusable (FAIR) principles be used to contextualise the impact of human decision-making on the research value of archaeological data, taking (as a test case) the Portable Antiquities Scheme (PAS) database of archaeological finds from England and Wales. The methodology used here examines data recorded within the PAS database directly and through a separate web application demonstrator (PASampo) that is being developed. The latter, in particular, enables ease-to-use visualisation of the data to provide an analytical evaluation of how data is inputted into the PAS database and, more significantly, how the researcher might extract this data. Through a series of case studies exploring aspects of material culture, we will highlight how data

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quality is affected by human decision-making alongside elements of the database framework. We will then argue that this provides the basis for new learning alongside adopting FAIR principles that could benefit the development of a wide range of future archaeological and cultural heritage databases, including the PAS database itself.

CCS Concepts: • **Information systems → Web searching and information discovery**; • **Applied computing → Arts and humanities**;

Additional Key Words and Phrases: archaeology, data, databases, finds recording, portable antiquities, material culture

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1 Introduction

Databases are generally created with the needs of primary users in mind, considering (in particular) how they will use them and what they might wish to extract from them. Thereafter, database developers might consider the needs of other potential communities, but not usually to the detriment of primary users. As such, this might mean that a database holds valuable information for others, but whether it can be easily extracted and exploited in full depends upon the application and the extent to which **Findable, Accessible, Interoperable, Reusable (FAIR)** principles have been (or can be) applied. For example, a numismatist might create a database of coin data for their use. Since it is obvious that all the items are coins, they may not record that basic fact. Similarly, they might know that certain denominations, e.g., English medieval pennies, are always of a particular composition (i.e., silver), so omit that detail. Also, some coins are so well classified that a reference number, e.g., Class 2b, as used on 'long-cross' pennies, overrides the necessity to add related descriptive information simply for the sake of making efficiencies in entering data: this could include the exact form of the king's image on the coin, the number of curls in the hair, pellets on the crown and so on. As such, the owner or creator of such a database might not foresee (or consider important) its use by others with divergent needs. This 'missing' information might become a more serious omission if, for example, these data are migrated into or combined with a database of non-numismatic material. In this case, it would be impossible for new users to search for items made of silver or that depict crowns. Such issues may seem obvious, but are often overlooked and essential to consider. This is especially so given heritage databases can have long lifespans and the chances are growing—given the desire to log data and extract information from old datasets (and because of various transnational cultural heritage data aggregation efforts, as discussed below)—that other users might wish to migrate old data for a different purpose than originally intended. The following discussion will explore both the impact of human decision-making on the research value of archaeological data and the advantages (but also the limitations) of applying FAIR principles to creating archaeological databases.

FAIR principles aim to make data 'Findable', 'Accessible', 'Interoperable' and 'Reusable' [48][1]:

— *Findability*: F1. (Meta)data are assigned a globally unique and persistent identifier; F2. Data are described with rich metadata (defined by R1 below); F3. Metadata clearly and explicitly includes the identifier of the data they describe; F4. (Meta)data are registered or indexed in a searchable resource.
— *Accessible*: A1. (Meta)data are retrievable by their identifier using a standardised communications protocol; A2. Metadata is accessible, even when the data are no longer available.

[1]The FAIR principles are listed here and their numbering are based on https://www.go-fair.org/fair-principles/.

— *Interoperable*: I1. (Meta)data uses a formal, accessible, shared and broadly applicable language for knowledge representation; I2. (Meta)data uses vocabularies that follow FAIR principles; I3. (Meta)data includes qualified references to other (meta)data.
— *Reusable*: R1. (Meta)data are richly described with a plurality of accurate and relevant attributes.

These principles seem logical enough, but database developers (working with end users) must make crucial decisions to create 'FAIR' data. This includes, but is not limited to:

(1) What functionalities and services are needed from the end user's point of view?
(2) What (meta)data model [40, 49] to use for describing the artefacts, e.g., Dublin Core[2] or its derivatives, CIDOC **Conceptual Reference Model (CRM)**[3], or its extensions, such as CRMarchaeo[4] and Nomisma[5]?
(3) What 'controlled vocabularies' [16], i.e., **Knowledge Organization Systems (KOS)**[6] [50], are used in populating the metadata element values (e.g., for object type, material, time/period, place of manufacture, findspot)[7]? Several options are available, such as the Getty Art and Architecture Thesaurus[8] for artefacts and PeriodO[9] for times and periods used to harmonise linked data thesauri in the pan-European ARIADNEplus infrastructure and portal[10].
(4) What practices are used for cataloguing the artefacts[11]? For example, what metadata fields are required and optional, what kind of (and how detailed in content) descriptions are needed, and how to represent uncertain dates [13] and express them and so on. Cataloguing practices are especially well-developed for bibliographical records[12].

Once decisions on points (1) and (2) have been made and the database user interfaces are implemented, points (3) and (4) remain practical challenges, as the specifications for creating the database typically leave scope for users to input data in various ways. This is especially true when using string-based annotations and textual descriptions that are ambiguous to a machine. A remedy is to use controlled KOS with unique identifiers. Still, quality issues arise even then, as the KOS are seldom complete and different users tend to make individual selections based on what seems logical, leading to low inter-annotator agreement [1], hence the impact of human decision-making on the data quality. The challenges are emphasised when many users, especially those without a professional recording background, input data, e.g., as in 'citizen science archaeology' [41], of which the **Portable Antiquities Scheme (PAS)** database (see below) is a good example.

Controlled language and drop-downs for recording data might be used to group and harmonise data and limit the risk of human error[13], but these tools are not fool-proof guarantees for capturing high-quality data, hence creating challenges for applying FAIR principles to archaeological datasets. Similarly, training database users and providing clear documentation (metadata or otherwise) that offers consistent guidelines and is an authoritative point of reference might be an obvious way of ensuring consistency in data inputting. However, invariably users tend to develop their own habits. These could include misunderstandings based on, for example, outdated guidance information, but perhaps more likely are considered choices related to enhancing recording efficiency.

[2]Dublin Core Metadata Initiative: https://dublincore.org.
[3]CIDOC CRM: https://cidoc-crm.org.
[4]CRMarchaeo extension of CIDOC CRM: https://www.cidoc-crm.org/crmarchaeo/home-3.
[5]Nomisma.org collaborative project: https://nomisma.org.
[6]Encyclopedia of Knowledge Organization: https://www.isko.org/cyclo/kos.
[7]Here we use 'controlled vocabularies', 'thesauri', 'ontologies' and 'typologies' as synonymous terms, to mean a structured language.
[8]Getty Art and Architecture Thesaurus: https://www.getty.edu/research/tools/vocabularies/aat/.
[9]PeriodO gazetteer of periods for linking and visualising data: https://perio.do.
[10]ARIADNE infrastructure: https://ariadne-infrastructure.eu.
[11]E.g., https://www.getty.edu/research/tools/vocabularies/cco_cdwa_for_museums.pdf.
[12]See e.g., https://www.ala.org/pla/resources/tools/circulation-technical-services/cataloging-practices.
[13]Drop-downs on the PAS database include 'object type' for example, where users can only use the options available.

For example, not completing certain fields perceived as redundant (because the information can be inferred from the contents of other fields) saves time, enables faster production of new records and reduces the chance of manual input errors (e.g., typos) in free-text fields. However, when such choices are made on the level of the individual recorders on a case-by-case basis, the results across the whole database will be heterogeneous and uneven.

In response to the development and adoption of digital technologies in cultural heritage management, archaeological databases have proliferated in recent years [38]. With this comes a greater need to capture and explore paradata, or information on the processes by which the data were collected [11]. Although potentially relevant to all archaeological data, we focus our discussion in particular on large institutional databases, such as those published by national heritage agencies and finds recording schemes in many European countries (see e.g., [27, 28]). In terms of the impact of human decision-making, these typically possess some or all of the following characteristics:

— *Longevity*: Being developed across multiple generations of technological solutions and carrying the mark of the specific motivations or constraints each may impose.
— *Multi-user input*: Being generated by many users with often different backgrounds, data management interests, scientific expertise and levels of training.
— *Diverse user audiences*: Being accessed across a long period of time by a wide variety of end users with different needs, many of which were probably never considered during the initial database design or development processes.

Here, we take the PAS database[14] of archaeological finds made by the public in England and Wales as an example of such a dataset to consider in terms of how human decision-making can alter the research value of data, and where FAIR principles might help mitigate the challenges this presents but might not always be enough to do so. This is neither designed to be a criticism of the PAS database, nor a rejection of adopting FAIR principles in developing archaeological datasets, especially as the issues identified here are not unique to it. Still, it provides a good platform for this analysis for several reasons and highlights the challenges for developers of archaeological datasets in particular.

First, it is a large archaeological dataset, one of Europe's largest object databases, with over 1 million records describing more than 1.8 million individual objects of all types and periods. The records mostly represent a wide variety of 'portable antiquities' (coins, dress accessories, tools, household implements, etc.) discovered through avocational metal-detecting. Many people have inputted the data, 1,175 since 1997, and these 'recorders' will have varying skills, experience and expertise. Second, the people entering the data are based across England and Wales and, therefore, might have or have developed (as will be shown) regional/localised approaches to their work because of varying demands. That said, the processes for entering data into the PAS database are relatively robust: it follows a common thesaurus (albeit with some in-built peculiarities, as will be highlighted) in terms of logging finds types (and sub-types); it makes good use of drop-downs based on controlled vocabularies to encourage fields to be completed consistently; its staff, assistants, interns and volunteers are all trained in recording finds on the database; and there are guides on how recorders should enter specific data. Finally, the user audience of the PAS database reflects a wide range of people across the UK, as well as internationally, who are interested in material culture. These include professionals in heritage management, academic researchers, metal-detectorists and other finders, local historians, journalists, educators and school students and members of the public interested in the past.

As part of this study, a comprehensive data dump of (993,382 finds records) was downloaded on 29 June 2023 and analysed using the R[15] language. Additionally, a web application based on the Sampo-UI[16] framework, known as PASampo, was used to explore and visualise the data beyond what is possible in the current PAS database.

[14]PAS database: https://finds.org.uk/database.
[15]The R Project for Statistical Computing: https://www.r-project.org.
[16]See the source code of framework at https://github.com/SemanticComputing/sampo-ui, and for the use of the Sampo system in opening archaeological data, see [28, 32].

Mainly for this application, a simple **Resource Description Framework (RDF)**[17] format conversion of the data was created. The most current root data in the online PAS database was also queried where appropriate to search for individual object records and their photographs. As such, the research for this article has been performed using multiple tools to explore and analyse PAS data generated over 20 years.

The PAS database is currently undergoing a rebuild (2024–2026). Hence, the lessons learned here will likely be useful in its development and other archaeological databases; in the last decade or so, several other European databases for recording public finds have been established. Some, such as in Denmark[18] and Belgium[19], are particularly dependent on a citizen science approach [6, 46, 47], and are driven by recognition of the research value of public finds to advance archaeological knowledge [39]. Even so, this article offers a reminder of the importance of adopting FAIR principles in the development of archaeological databases, but also that data entry can cause biases, so researchers should be aware of these when using such datasets.

The following two case studies (both in two parts) further the issues outlined above. One explores data biases, and the other examines the specifics of recording certain object types. Thereafter, we will investigate how vocabularies impact data recording, aspects of data quality and semantic analysis.

2 Case Study A: Regional and Longitudinal Variation in Data Entry

This case study will explore how large multi-contributor archaeological databases may develop a lack of overall uniformity in data quality across their operational lifetime, something that the adoption of FAIR principles is designed to overcome. These examples are particularly pertinent from the FAIR perspectives of *interoperability* (e.g., because of the amalgamation of external data dumps into the main dataset) and their *reuse* (especially for large-scale computational analysis). Firstly, it will explore how and why the spatial precision of findspots (a critically important class of information) in the PAS database varies between regions. Secondly, it will consider how limited-term initiatives (here a drive to encourage the reporting of public finds of heavily corroded Roman coins, colloquially known as 'grots') may have a very positive yet uneven impact on the formation of the dataset, as well as introducing hidden biases that must be examined and understood if the data is to be reused for large-scale analysis.

2.1 Recording Spatial Precision

The precision of findspot data is paramount to interpret finds within their landscape context and to investigate their relationships to one another more generally. Metal-detected finds are typically recovered from the plough-zone and therefore lack any stratigraphic context that aids their interpretation. As such, wider spatial and landscape contexts are crucial in their study [5, 46]. Like most British archaeological spatial data, PAS findspot data is traditionally recorded using the **Ordnance Survey (OS) National Grid Reference (NGR)**[20] system, although What3Words[21] and other locational aids are becoming popular amongst finder communities. In the OS system, the NGR indicates the location of a square within which the find was made, with longer NGRs giving greater precision. As seen in Figure 1, most finds are given as 6-figure (precise within a 100 m^2), 8-figure (10 m) or 10-figure (1 m) references, although a minority (mostly older finds) are less precisely recorded. Before affordable hand-held GPS devices and smartphone apps, when findspots were mostly taken from printed maps, more precise NGRs were hard to obtain. Since 2003, the PAS has required finders to give at least a 6-figure NGR (e.g., TQ123123) and more recently (since 2015) at least an 8-figure NGR (e.g., TQ12341234). In 2022, at least 82% of new finds were recorded to at least an 8-figure NGR, and 74% had at least a 10-figure NGR [22, p. 39]. Given that most 'portable antiquities' are from the plough-zone (93% in 2022), where they are likely moved from their original place of deposition by the action of agricultural machinery, this is regarded as a good working precision in most cases.

[17] RDF: https://www.w3.org/RDF/.
[18] Digitale Metaldetektorfund: https://metaldetektorfund.dk/ny/.
[19] Metaaldetectie en Archeologie: https://medea.weopendata.com.
[20] National Grid Reference system: https://epsg.io/27700.
[21] What3Words: https://what3words.com.

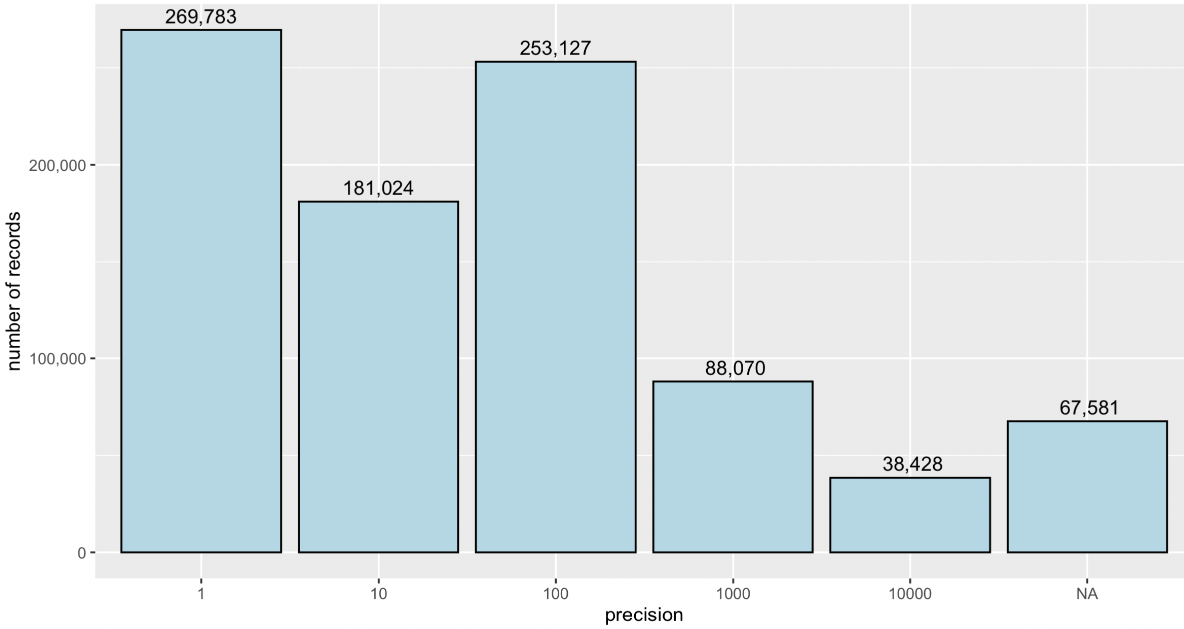

Fig. 1. PAS finds by NGR spatial precision. 1 = precise to 1 m^2. A small number (855) of finds with greater given precision than 1 were rolled into that category.

Other factors impact the character and quality of the data. Figure 2 shows (on a yellow-green-blue colour scale) a mathematically calculated map surface laid over England and Wales. This illustrates a variation in the local recording of findspot precision, computed using the *Smooth* function of the R *spatstat* package[22]. Regions with no, or a very low density of, finds have been removed to even out statistical anomalies. The visualisation shows a clear regional variation across England and Wales. The Isle of Wight, off the south coast, and most of Wales, in the west of Britain, appear to have (on average) the most precise spatial data. Another significant divide lies roughly between northern and southern England, with finds records from the south having better spatial precision. From this, it is possible to make several observations that illustrate the characteristics of the PAS database, with broader relevance to similar archaeological databases, and that are important to consider for the effective implementation of FAIR principles:

(a) *Recording and community relations*: The role of local **Finds Liaison Officers (FLOs)**, primarily responsible for recording finds onto the database, is critical. The high spatial precision achieved on the Isle of Wight is largely due to the work of a long-standing FLO (2003–2020) who had good relations with the local detecting community. In contrast, the high turnover of Essex FLOs (seven since 2003; Essex being the predominantly blue area on the south-eastern coast above the Thames estuary) and broader issues of some local detectorists being less willing to work with archaeologists highlight the importance of continuity and ongoing liaison between archaeologists and finder communities, thus resulting in more and higher quality records [36].

(b) *Reporting practice locally*: Hundreds of recorders have contributed to the PAS database, logging information from thousands of finders over more than 20 years [3, 21]. The PAS was established following long-term animosity between archaeologists and finder groups [21, 43], with suspicions towards collaboration with archaeologists lingering longer in some regions than others. This might be reflected in the difference in findspot precision

[22] R spatsat homepage: https://cran.r-project.org/web/packages/spatstat/; Example code workflow for conducting this analysis is published at Zenodo: https://doi.org/10.5281/zenodo.14918472.

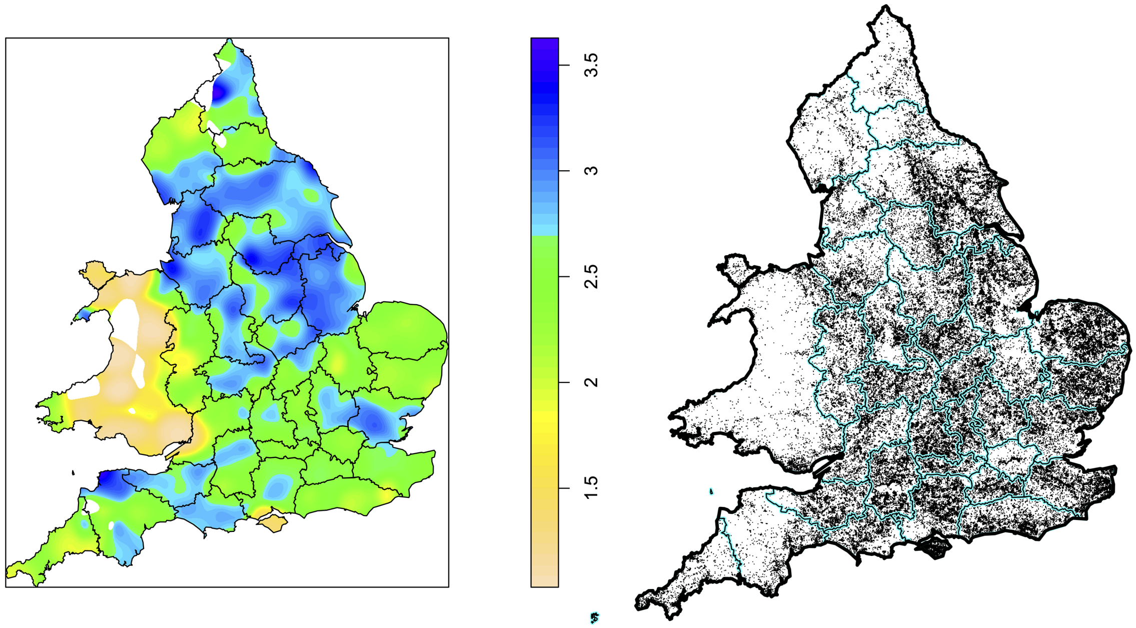

Fig. 2. Local average of findspot accuracy across England and Wales (sigma = 10 km) (left), and the distribution of findspots with coordinate values (954,161) (right). To assist with analysis and visualisation, findspot accuracy has been translated so that the progression is not by an order of magnitude (1, 10, 100, etc.) but rather that 1 = precise to 1 m, 2 = 10 m and so on. Variation in values within the computed surface is therefore relative.

between northern and southern England highlighted above, as (even now) northern FLOs note the reticence of higher proportions of finders giving precise findspot information compared to those in the south. It is also the case that finders in the south are more likely to make finds than in the far north—given the considerable differences in historical population densities and, therefore, the amount of material culture to be recovered (see e.g., [8, 30])—so become more familiar (and comfortable) with finds recording.

(c) *Data harmonisation*: Merging external data dumps into a database without fully processing and harmonising them will create anomalies. The apparent high findspot precision in Wales is a product of the inclusion of records from the **Celtic Coin Index**[23] **(CCI)** (37,844 records) and the **Iron Age and Roman Coins of Wales**[24] **(IARCW)** (52,812 records) databases, both added in 2010. These projects are external to the PAS, yet amount to almost 10% of all PAS records, digitised coins from existing archives, excavation reports and other sources. Their inclusion is anomalous, for the PAS database is conceived today mainly as a repository for recording public finds. They reflect how ideas about what kind of records the PAS should log and share have evolved over its operational lifetime. Furthermore, these data sources and recording practices differ from the workflows adopted by the PAS. In many cases, for example, the spatial coordinate associated with a given coin record is a high-precision spatial coordinate for the centre point of an excavation area rather than the object's actual findspot. The CCI and IARCW coordinates are no less precise *per se* but encode a different class of spatial information—a difference that can be accounted for but is not obvious to most end users. This highlights the need to be transparent about how datasets are constructed to unlock the data's fullest reuse potential. To this end, functionality (even advice) could be added to databases that allows end users to identify such (seemingly) anomalous data dumps more easily.

[23]CCI: https://cci.arch.ox.ac.uk/pages/info.
[24]IARCW: https://doi.org/10.5284/1000263.

2.2 Impact of Educational Outreach

In the next case study, we conceptualise challenges related to the *interoperability* of PAS data not only extrinsically (between PAS and other heritage databases) but also internally; that is, within and between the different data blocks accumulated within it during its lifetime. The creation of the PAS dataset has not always been a gradual accumulation of records, as there have been periods when its size has leapt forward. This has been particularly so regarding Roman coins, the most commonly reported find type in England: 297,747 items on 29 June 2023, representing 30% of all finds.

The decision to report a find is the penultimate 'stage' in which an object must pass on its journey from deposition to becoming a database record [36, 37][25]. Appreciating the find's archaeological or other cultural heritage value typically informs this. Many detectorists do not always see great individual value in the small late Roman copper-alloy coins found in large numbers, especially if they are poorly preserved. The significant archaeological and numismatic value of these 'grots' lies in the possibilities they offer in charting *en mass* hitherto poorly understood patterns in the Roman economy and money circulation. Moreover, certain low-denomination copper coins are actually scarce in Britain, with only a few examples known, and therefore are important sources of information. Specific issues of these coins can even be linked to particular events, such as movements of the Roman Army, and may therefore yield singular evidence relating to them; so far, this research has concentrated on earlier Roman coinage, suggesting the still untapped potential present in expanding it to the later material. More generally, the significant numbers of Roman coins recorded by the PAS have been used to investigate economic developments, both regionally and across large geographical regions, including tackling such major topics as the end of Roman Britain [4, 25, 44, 45].

The impact created by a short but concentrated educational outreach project on the PAS database can be seen most spectacularly in the case of these coins. In 2007, Sam Moorhead, then PAS National Finds Adviser for Iron Age and Roman Coins, embarked on a tour of detecting clubs across England, promoting the reporting of Roman 'grots' [26, pp. 3–7]. The results are seen in Figure 3, which displays a significant peak in late Roman coins recorded from *c.* AD 238, Reece period 12 [34, 35][26], during that year. It is noteworthy that while this does not seem to have impacted upon the annual numbers of new Roman 'non-coin' finds recorded, which has remained more or less static between the PAS becoming a national project in 2003 and the COVID-19 pandemic of 2020, there was an almost an equally impressive increase in coin records from other periods—numismatic data was put on the map on a new level. Although the numbers came down the following year, there was a sustained overall annual increase in coins (both Roman and non-Roman, but especially late Roman coins) recorded on the database. The fact that a large number of the coins recorded in 2007 had been discovered sometime before and not previously reported is shown by the fact that the median date of discovery (when this information is recorded) for these coins is in September 2005. In contrast, for all other years (2003–2020), the reported time of discovery was either during that same year or in the last quarter of the previous year. The 'grot drive' was clearly a very successful educational enterprise, significantly benefiting archaeological and numismatic understanding of the past.

Notably, the PAS database did not digest the data without leaving characteristic traces, which is important to consider in the context of the impact of human decision-making on the research value of archaeological data. How to effectively represent this within the framework of FAIR principles is a continuing challenge. The result of detectorists handing over large collections of old finds in 2007 led to a lower than average quality of record data. This is especially seen in Norfolk, where over 11,000 old finds were brought in for recording (cf. [18, p. 173]). 'Primary material' is one of the most consistently completed fields in the PAS database, with 98% of all records containing this information. In the case of Norfolk coin records made in 2007, the material field was left empty 95% of the time. In addition, most records did not contain an image of the find. New records of old coin finds also impacted the quality of location data. In 85% of the Norfolk coin records logged in 2007 with coordinate data

[25]See also the PAS Guide for Researchers: https://finds.org.uk/research/advice.
[26]Reece periods in PAS: https://finds.org.uk/romancoins/reeceperiods.

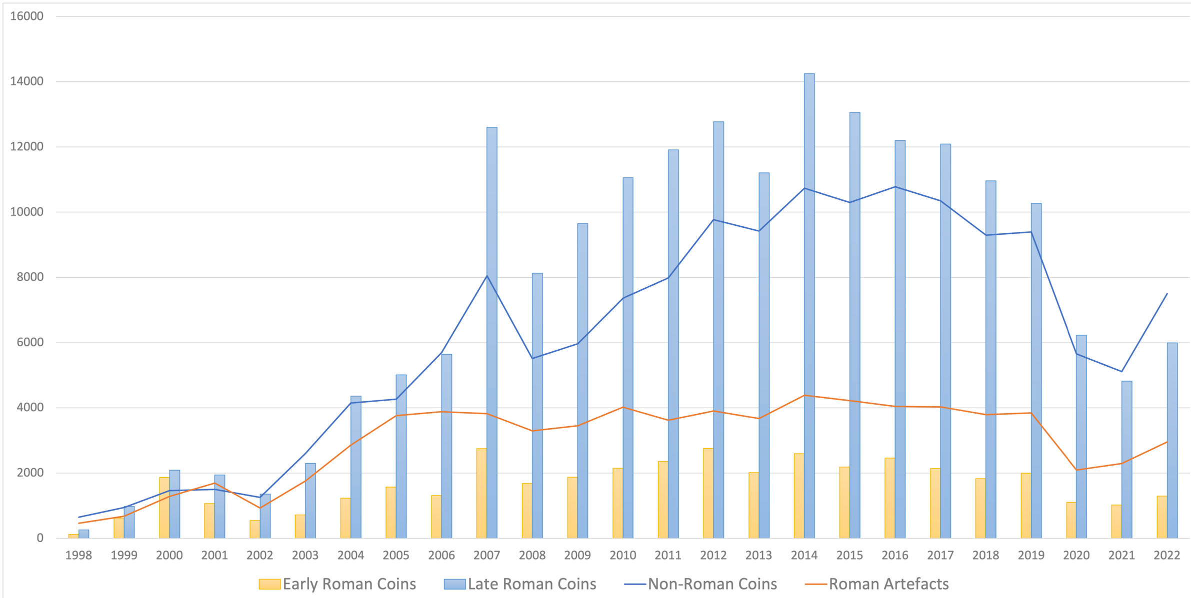

Fig. 3. Selection of different object types recorded in the PAS database 1998–2022. Data dumps from external projects have not been included in the figures.

(10,444) the NGR is given as a 10-figure reference (i.e., 1 m), but this is misleading. Closer examination shows that finds are grouped into only 1,212 individual findspots. This suggests that it was impossible to obtain good quality findspot information on these older finds, some going back to the 1990s, and many collections (including some containing hundreds of coins) were thus given a single 'centre of field' findspot.

In a way, these collections of old finds can also be conceptualised as 'external data dumps', at least in the sense that they were reported and recorded using somewhat different principles than most of the other finds in the PAS database. The quality and character of the records they contain may vary from that of the parent PAS dataset, posing *interoperability*-related challenges on how (if at all) these differences can be captured and represented. This is not to denigrate the goodwill or effort put into creating this considerable amount of new information, one which possesses great research potential. But from a data management perspective, such exercises can lead to problems with *interoperability* and *reuse*, especially given that the large amounts of data generated are attractive for computational archaeology (e.g., [2, 7]). Statistical and Geographic Information Systems analyses examining the spatial properties of the finds would yield skewed results if the special characteristics of the local data were not identified and controlled for. Yet, this information is unobtainable except through a targeted and fine-grained search for anomalous patterns in the PAS database and must be known by the researcher to be adequately processed and contextualised. This highlights the importance of documenting and publishing the process history of data creation in accessible metadata and paradata formats, as will be highlighted later. This is especially true for large cultural heritage databases (see also [27]), where data creation conventions may have varied across their operational lifetimes, as in the examples above.

3 Case Study B: Object Types

This case study will illustrate the complexities of recording certain object types and the possible impact this has on data for research, notably how *findable* and *accessible* it is. Firstly, coins (again) are investigated. As has been noted, these are particularly numerous within the PAS dataset, but also have to be approached somewhat differently because of certain unique attributes. As such, they present a challenge when recorded in a dataset including non-numismatic items. Secondly, we explore challenges with applying controlled vocabularies when certain artefact types might be open to varying interpretations, with a case example discussing pilgrim badges and other (usually secular) badge types. Both examples highlight the advantage of adopting FAIR principles to archaeological datasets, especially to contextualise the impact of human decision-making on the research quality of such data.

3.1 Coins as Standardised Objects

Coins are the most common type of find recovered and reported by detectorists in many European countries, including England and Wales [29]. They have generally been mass-produced, are easy to classify, and are easily recognised by finders. In the PAS database, coin records constitute approximately 50% of all PAS records. Most are described according to internationally used standards, discussed below. Various drop-down menu options using controlled vocabularies are available in the recording form beside free-text fields. For the users, the advanced numismatic search based on different historical periods (Iron Age, Roman, medieval, etc.) enables a detailed search for certain very specific coin features, including information on, for example, the die axis, inscriptions and so on.

In a monetised society, coins are primarily a means of exchange, with their most important feature being reliability (i.e., users of coins have to trust their face value without retesting their weight and precious metal content). Throughout history, coins have retained their function as standardised objects; with some exceptions, they are invariably round and made of metal. The minting authority determined a coin's value, usually indicated through iconography and text on the coin, as well as its size and weight. In addition to the value, coins may also name the ruler under which the coin was issued and the place where it was minted. These aspects, which (in most cases, except in debased small-change) guaranteed confidence in coinage for users hundreds of years ago, are the same features which form the base for typologies used today when identifying and describing coins [15, p. 94]). These numismatic typologies have a long history, as the first coin collections in Europe were established during the Renaissance, and coins were among the first objects to be accessioned into museums in the 18th century.

Due to the physical aspects of coins, the history of coin collecting and numismatics as a scientific discipline, the cataloguing and recording of coins can differ significantly from other archaeological objects. There are established customs used when describing a coin to create a complete picture of its physical attributes (e.g., material, manufacture, weight, diameter, die axis), geographic context (e.g., mint, region, findspot), issuing authority and other personal aspects (e.g., state, ruler, issuer, engraver), chronology (date), description (e.g., denomination, weight standard, as well as detailed descriptions of the obverse, the reverse and the edge) and condition (wear and completeness). Standardised references are also widely applied[27], and digital projects, such as Nomisma.org, strive to provide stable concepts for recording coins within the principles of Linked Open Data, therefore inherently addressing data *interoperability*, which can help to harmonise numismatic data further.

The fact that the PAS database, despite containing an enormous number of coin records, is not a dedicated numismatic database results in certain heterogeneity in data consistency (see Figure 4). Material, an attribute relevant to all archaeology, is documented in 97.6% of cases, but weight in only 72%, and diameter in 63%. Sometimes in the PAS dataset the diameter has been replaced by length or height, which are not standard values when cataloguing coins, but useful when recording coins that are very worn, or have been cut in half or into quarters for use as lower denominations; this recording usage is an example of specialist knowledge that some users cannot be expected to command and highlights the challenges of combining numismatic and non-coin data. The denomination field is well used when it comes to Roman coins. Still, for the medieval period, it was left out in 10% of the entries recorded with the PAS, presumably because the 'penny' was the standard silver coin in England for much of the medieval period (from c. AD 855 for the next 500 years), and this attribute is, therefore,

[27] How to catalogue, digitise and move a collection of coins (Bibliothèque nationale de France): https://bnf.fr/en/how-catalogue-digitise-and-move-collection-coins-simple-tip.

	All (n = 484 632)	Roman (n = 294 308)	Medieval (n = 81 454)
Material	97.50%	97%	98%
Region	95%	98%	97%
County	96.50%	99.50%	99.50%
Parish	95.50%	99%	98.50%
Institution	100%	100%	100%
Period	100%	100%	100%
Mint	47%	45%	71%
Ruler	85%	92%	87%
Denomination	95%	98%	89.50%
Discovery method	86%	82%	100%
Preservation	21.50%	20%	28%
Completeness	66%	66%	84%
Length	4%	3%	9%
Thickness	25%	24%	33%
Height	0.01%	0.01%	0.01%
Weight	73%	66.50%	80%
Diameter	63%	66%	69%
Quantity	100%	100%	100%

Fig. 4. Recording frequency of various attributes related to coins in the PAS database, as obtained through the PASampo statistical tools.

implicit. Reflecting the fact that it is an *archaeological* database, the lack of information may also be due to the condition of the object; PAS finds, like most archaeological finds, are recovered from the soil and may be in such a poor condition that many features are illegible.

Due to both the large number and the specific nature of coins, numismatic objects have achieved a special status in the PAS database. Separate numismatic guides and detailed recording schemas are available to those using the PAS database and designed to fit traditional numismatic research. The level of information used when recording coins on the database understandably varies depending on the knowledge of the recorder and how much time they have to make a record. Although recording coins with the PAS usually follows certain established practices, searching for specific aspects (especially outside traditional numismatic values, such as issuer, material and denomination) is more complicated. Coins in the PAS dataset are generally considered objects of commerce, but a coin may also acquire a secondary function during its life. These shifting roles can be challenging to identify, especially for finds lacking a precise archaeological context (typical for detector finds) and, therefore, without extra information about why they have been deposited. Perforated (possibly used as dress accessories or amulets), folded (an action that can be interpreted as part of a ritual such as a pilgrimage offering) and clipped coins (indicating the object was valued principally as a store of precious metal, rather than for its formal face value) are the easiest to distinguish (see e.g., [14]). Sometimes, it is harder to observe the difference between pre-depositional damage and that made later, once an item is lost in the ground, such as by farm machinery. In the PAS database, there is the 'reuse' field for this search facet, but it is not always completed. Therefore, the most comprehensive way to locate items in the PAS database with these attributes is by using the free text search and opening individual records to examine natural language object descriptions and photos. This can be a cumbersome

Fig. 5. Folded silver short cross penny of Henry II, c. 1180–85, found in Houghton, Hampshire (PAS: SUSS-2714DD).

process, as certain text searches (such as for the character string 'folded') will bring up hundreds of records, many of which are irrelevant (such as coins showing figures with folded garments rather than folded coins).

Wear and completeness are also values that are less frequently used in PAS coin entries, with information lacking in 34% of the cases (see Figure 5). The details about completeness are incomplete in itself, as it would require a further drop-down (in addition to what already exists) describing whether the coin has been accidentally broken or intentionally modified. Sometimes, this value has even been used for extremely worn or misstruck coins, describing completely different phenomena. A more thorough use of drop-downs is time-consuming for the person recording such items, but on the other hand, it could reduce the need for free text descriptions. Significantly, for already well-standardised objects like coins, it would further minimise the risk of definitions open to interpretation.

3.2 Badges vs. Pilgrim Badges

Pilgrim badges, as their name suggests, were made for pilgrims visiting holy places. They served as both a memento or souvenir of that visit, but also, when touched upon holy relics, they were believed to be invested with properties that could protect and cure (i.e., as secondary relics). They became popular in the Middle Ages, alongside 'secular' and other religious badges. Here, they are a useful object type to highlight in this article since pilgrim badges have specific attributes which might not always be obvious or apparent to those recording them. Hence, when logged in archaeological datasets, like the PAS database, they can be difficult for the researcher to *access* or *find* if not recorded consistently.

The PAS 'finds guide' for 'pilgrim badges'[28] advises database users to record medieval pilgrim badges as a 'PILGRIM BADGE' (Figure 7) in the 'object type' drop-down, as opposed to 'BADGE' (Figure 8), which should be used for 'secular' and 'livery' badges.[29] In fact, this taxonomy might be too simplistic since there are other 'religious badges' (i.e., devotional badges) that might not have all the characteristics of a pilgrim badge, such as a

[28]Pilgrim Badges in PAS: https://finds.org.uk/counties/findsrecordingguides/pilgrim-badges/.
[29]Badges in PAS: https://finds.org.uk/counties/findsrecordingguides/badges/.

visual/textual focus on a saint's cult. The essential point here is that categorical typologies are imperfect models for many items of material culture [10].

It might not always be obvious to a recorder if a badge is a pilgrim badge or not, or even religious or not, or even if that distinction (between religious and secular) makes sense in terms of the medieval worldview, where the realms of religion and everyday life were blurred. Indeed, some (so-called) 'secular' badges are inspired by 'religious' counterparts. Notable are badges of St George, which, unlike most pilgrim badges, are usually made of silver, suggesting that they might be secular badges instead [20, 23]. Similarly, it has also been argued that 'profane' badges, so usually depicting a phallus and/or vulva, or sex scenes, might have religious connotations. Whatever the theoretical complexities determining whether a badge is a pilgrim badge or not (see [20, 42]), the guidance to those making records on the PAS database is clear (see above)—'pilgrim badges' should be recorded as pilgrim badges and other 'badges' should be recorded as (just) badges. Nonetheless, this guidance is not always followed due to human decision-making, creating issues for end users of this data.

The PAS database has 769 finds records identified as 'medieval' (broad period) and 'pilgrim badge' (object type). A further 327 are 'medieval' (broad period) and 'badge' (object type). This suggests the latter should be medieval 'badges', such as livery badges and similar. However, some recorders have used 'badge' for items that might be pilgrim badges, or religious badges more generally, but cannot be identified with certainty. A 'badge' from Great Oxendon, Northamptonshire (LEIC-25DBA9: Figure 9), for instance, is decorated with a likely female bust in profile. The recorder suggests this is 'possibly the Virgin Mary', but is clearly unsure, and rightly so. The image is difficult to distinguish in the case of a badge from Leckhampstead, Buckinghamshire (BUC-6E8E43). Even so, the recorder says the object is 'possibly a pilgrim badge' and might show St John the Baptist, the Vera Icon or St Thomas of Canterbury!

Conversely, some items recorded as 'badges' are actually 'pilgrim badges' and have even been identified within the record as such, even if this has not been recorded using the 'object type' drop-down. These include one from Glemsford, Suffolk (SF-527947: Figure 10) showing the Annunciation (when the Angel Gabriel came to Mary bearing news that she was pregnant), and another, found at Wakefield, South Yorkshire (SWYOR-E2D028), of the unofficial cult of King Henry VI of England (1421–1471). Here, then, it would appear that human error has resulted in pilgrim badges being recorded as badges.

Usually, badges recorded as 'badge' are secular (though, as noted, this might not always be the case), and examples include several heart-shaped items (e.g., SWYOR-9132FB and NLM-28F731), usually interpreted as love tokens, but perhaps they might be livery badges. A further complication is that not all 'badges' are certainly badges. For instance, an 'unidentified object' from Dobwalls and Trewidland, Cornwall (CORN-98B552), has been recorded as a 'badge', though it appears to have a stud-like projection, more typical of 'mounts' (to embellish dress accessories, furniture, etc.), rather than a pin or attachment loop. Even so, it is like a pilgrim badge in terms of its composition and form, highlighting the limitations of the controlled vocabulary used and the challenge for those wishing to follow FAIR principles in database design.

It could be argued that the ambiguous assignment of possible or actual 'pilgrim badges' as just 'badges' matters little, as a search of 'badge' on the PAS database brings up all the badges, including the pilgrim badges. The databases' filter function then enables certain attributes to be targeted (e.g., types of material composition), *found* and made *accessible*. However, with more and more data being added to the PAS database, it is becoming harder for researchers to find items if they are not where they might expect to see them.

Most items recorded as 'pilgrim badge' are religious, as might be expected, but there are some anomalies. Recorded on the PAS database is a heart-shaped pendant from Bradbury and the Isle, County Durham (DUR-F183F4), similar to the heart-shaped 'secular' badges mentioned above. In addition, some badges from Southwark and Queenhithe, London (LON-CA95FB and LON-1048B7), are in the form of a *gisarme* (axe-like weapon). It is not clear why these had been recorded as pilgrim badges rather than badges, and the records have now been corrected. Pendants also present a challenge for recorders, especially those that are badge-like. A series of lead-alloy pendants showing St Margaret of Antioch (on one side) with the Christogram 'IHS' (on the other) are

	Pilgrim Badge	Badge	Other Religious
Saint/Religious Scene	Yes	Maybe	Maybe
Linked to Cult Centre	Yes	No	Maybe
Pin/loops	Yes	Yes	No
Composition	Usually lead	Any metal	Any metal

Fig. 6. Characteristics of ‘pilgrim badges’ against other ‘badges’ and ‘other’ similar objects (like other religious badges not explicitly related to pilgrimage or cult sites).

Fig. 7. Lead-alloy medieval ‘pilgrim badge’ showing the bust reliquary of St Thomas (Becket) of Canterbury, found at Millwall, London (PAS: LON-2B684D).

prevalent in Lincolnshire (e.g., NLM-BECE1A, NLM-02E8A7: Figure 11 and LIN-4A9334), and therefore have been identified with the local cult centre of Ketsby [19]. Somewhat incorrectly, they have traditionally been recorded as pilgrim badges, though they are certainly pendants.

Some badges, often continental, have loops, distinguishing them from other pilgrim badges. Examples include those associated with St Eloi (YORYM-6BC577), St Guilhem (YORYM-F112E1) and St Peter and St Paul (NMS-D08520 and OXON-0C414B). Others, such as that in the form of a purse from Wickwar, Gloucestershire (GLO-E0E35D), are also perhaps religious—thought to be associated with St James ‘the Great’—but could be a ‘secular’ charm. Others are almost undoubtedly secular, including a badge from Queenhithe, London (LON-104804), showing a female and male bust, each within a frame, with suspension loops above. Another object type sometimes finding its way amongst ‘pilgrim badges’ on the PAS database are *ampullae*, lead vessels to hold holy water or liquids and associated with saints’ cults (e.g., LANCUM-6A194E: Figure 12 and LANCUM-0AB780), and even Canterbury bells (KENT-EC8680). In short, the items recorded as pilgrim badges show inconsistency in using that term due to human judgement, making it harder for researchers and others to *find* and *access* them (Figure 6). How, then, to address these challenges?

4 Data Validation for Identifying Human Errors in the Recording Process

Approaches for detecting human errors or finding anomalies in data inputted in databases, such as those described in the above case studies, include various data validation techniques. For example, recent advances in Linked

Fig. 8. Silver-gilt medieval livery 'badge' showing a stag's head, found at Beal, North Yorkshire (PAS: SWYOR-625C53).

Fig. 9. Lead-alloy 'badge' showing a likely female bust, perhaps the Virgin Mary, found at Great Oxendon, Northamptonshire (PAS: LEIC-25DBA9).

Fig. 10. Lead-alloy 'pilgrim badge' originally recorded as a 'badge' showing a scene of the Annunciation, found at Glemsford, Suffolk (PAS: SF-527947).

Fig. 11. Lead-alloy religious pendant recorded as a 'pilgrim badge' showing St Margaret of Antioch (on one side) and the Christogram IHS (on the other), found at Willoughby with Sloothby, Lincolnshire (PAS: NLM-02E8A7).

Fig. 12. Lead-alloy medieval pilgrim's *ampulla* originally recorded as a 'pilgrim badge', found at Thornley, Lancashire (PAS: LANCUM-6A194E).

Data include **Shapes Constraint Language (SHACL)**[30] and **Shape Expression Language (ShEx)**,[31] machine-processable languages for validating data against a set of conditions [17]. These integrity constraints specify the 'shape' that the data must conform to in order to be semantically valid. Based on these languages, there exists 'validation software'[32] that can be used to 'define' and 'check' parts of datasets and (thereafter) produce a report that states whether the dataset conforms to predetermined 'shape definitions' and lists possible violations. It seems that these approaches would help ensure that archaeological databases, such as the PAS database, can better follow FAIR principles.

As a demonstration, a small-scale data validation experiment was created using the PAS dataset within PASampo, focusing on periods and dates. The PAS uses a broad period classification for finds, following **Forum on Information Standards in Heritage (FISH)** vocabularies, which includes (chronological) date ranges for 'archaeological periods'[33]. Additionally, the PAS records individual finds (i.e., unique records with the PAS

[30]SHACL: https://www.w3.org/TR/shacl/.
[31]ShEx: https://shex.io.
[32]E.g., Apache Jena SHACL: https://jena.apache.org/documentation/shacl/.
[33]FISH thesauri: https://www.heritage-standards.org.uk.

database, replicated with PASampo) with a date range ('from date'—'to date'), allowing for more precise temporal recording than the broad period classification. To interrogate these data, a SHACL shape was created[34] that states that the 'from date' has to be 'less than or equal to' the 'to date'. When validating the data with a SHACL 'validator', it is possible to identify finds with a 'from date' recorded as later than the 'to date'. Such anomalies are probably human errors in the data recording process—e.g., incidents where the user has possibly mixed the 'from' and 'to' dates. This included some 2,000 errors of this type, including, for example, an Iron Age quarter *stater* (KENT-CC89C1) recorded with the date range AD 80–60; the correct date is 80–60 BC, as the textual description of the find states that it was 'minted between *c.* 80–60 BC'.

To investigate possible errors in the use of the period classification of the finds data, a SHACL shape that defines the 'from date' and 'to date' was created. This stated that finds cannot be dated earlier than the 'start date' or later than the 'end date' of a given period: thus, violations of the shape are cases where the 'from date' and/or 'to date' are outside the broad period's date range. In this example, it seems that the violations are caused by human error. Therefore, if adopted by the database designers, this tool can help ensure the data's integrity to better ensure that the database follows FAIR principles and its future value for researchers.

Nevertheless, and adding to the complexities of mitigating against such human error, it is also evident that some 'apparent errors' are explained by conflicts between the 'broad period' classification (which considers items within a 'national' context) and the 'find date' (that is not necessarily linked to that). For example, some 50,000 Roman coins were found to violate the 'shape', since their 'from date' is recorded as earlier than the period's start date: examples include a silver *denarius* (SWYOR-717483) dated to 122 BC and a copper-alloy *sestertius* (SF-E324F3) dated AD 1–250. In both cases, human error does not explain the apparent inconsistency. Instead, the FISH classification for the Roman period—AD 43–410, based on the Roman occupation of Britain—is at odds with the fact that Roman coins were being manufactured centuries earlier. These Roman Republican coins were being imported into Britain, informing on earlier Roman activity before the Roman occupation of Britain. In a numismatic and historical sense, these coins are certainly Roman, even though the period in question is still classified as the (British) Iron Age. Importantly, however, such validation tools could safeguard against human error when inputting data that could potentially violate broader chronologies.

In such cases, by validating the data, detected errors can be reported to the database owner. Some error types might be easy to fix, even with an automated process, whereas others need human consideration; here, a semi-automatic workflow could be utilised. In such a scenario, a domain specialist can be given a list of errors and suggestions for fixing them (e.g., a 'from date' later than 'to date' might be corrected by swapping the dates). Such errors found in this experiment could already have been prevented in the data recording phase by utilising validation mechanisms when inputting the data, including disallowing the user to add conflicting dates in the first place. A proposed validation workflow is presented in Figure 13.

5 Discussion

This article has set out real-world challenges and practical solutions in the development of large archaeological legacy databases to comply more with FAIR principles. We have shown that controlled vocabularies (such as thesauri, ontologies) are essential tools for enhancing data quality, not only when inputting data, but also for improving precision and recall when mining or searching databases, thus making data *accessible* and *findable*. As noted in the case studies above, recorders should use terms from a predetermined list of drop-downs for key data following industry-agreed vocabularies to enhance data quality. In general terms, the PAS database follows FISH vocabularies, though its creators have 'flattened' and adjusted the FISH thesaurus (i.e., hierarchy is not respected in the 'object-type' drop-down, and some new terms have been added)—something that will be addressed in the next iteration of the database. That aside, if these principles are followed, it is theoretically straightforward for recorders to choose the correct terms to 'describe' the items they record. Using an agreed vocabulary also

[34]The SHACL shape definitions used in this study are published at Zenodo: https://doi.org/10.5281/zenodo.14918472.

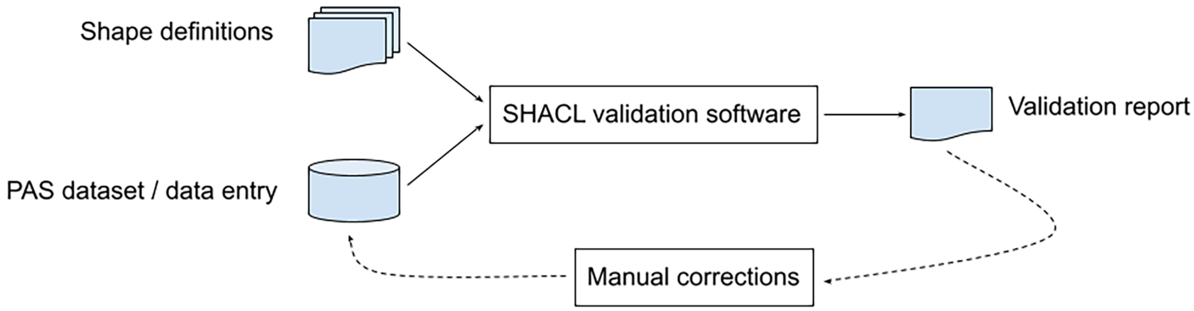

Fig. 13. Proposed SHACL validation workflow for the PAS dataset, either integrated in the data entry phase or as a separate data consistency check by the database owner.

means that researchers and other end users can refer to this to understand these terms and their relationship to each another. In short, controlled vocabularies (when used effectively) make it easier for end users to search for specific items and/or download data without speculating about every possible term for an item (or its attribute) that the recorder might have used.

Besides the work developers need to implement controlled vocabularies (versus free text entry) within a database, the case studies above show how multiple users can use drop-downs differently, even when fields are mandatory. This differing usage is sometimes likely to reflect the fundamental epistemological issue that controlled vocabularies, like all KOS, are imperfect in modelling the real world and cannot be taken as neutral representations of it (e.g., [9]). Highlighted above, concerning pilgrim and other badges, was the issue of how recorders might distinguish between object types based on their understanding of material culture and how such theoretical concepts fit within the medieval worldview. This could be a particularly critical issue for archaeology and cultural heritage studies. These subjects deal with highly complex contingent phenomena and processes where our understanding and research continually evolve, though likely to be replicated in other branches of science. Variance in the 'real world' application of a KOS (here expressed in the use of drop-downs to record material culture) is therefore also impacted by the human need to adapt a model to user needs and understandings that might change over time. Indeed, the PAS database has evolved much since its initial inception and delivery in 2003 [31].

Clearly, and of fundamental importance, using controlled vocabularies is not enough to solve all the potential issues human decision-making can bring to a database. Recorders can still use different terms through personal choice, either because there are quirks in the controlled vocabulary, the options given do not seem appropriate for those inputting data, or recorders lack knowledge or training, or simply through error. Here, it is also essential to note that those inputting data might not be using it themselves and, therefore, might not fully appreciate the nuances of their decisions. With PAS numismatic data, as a case in point and highlighted above, it is clear that some coin attributes are valued less by some recorders than others, even when a drop-down or choice of another field exists. This is likely due to the time they have to record these items—especially with the growth of metal detecting and the pressures this puts on those recording such items [24]. Invariably, where data are missing, these attributes are unavailable in any search, impacting the dataset's overall value as a research tool.

Focusing on recording particular information over other kinds of data can also lead to biases in the data, as shown above. Sections of the PAS database (like many long-standing cultural heritage datasets) have been subject to different data production processes: some originate from external data dumps (such as the inclusion of the CCI and IARCW datasets) and the intense but time-limited recording of large quantities of certain object types (for instance, Roman 'grots'). The specific characteristics of these records are poorly (or not at all) represented in the archaeological metadata, leading to problems with data being *interoperable* and *reusable*.

Also apparent in the PAS database are differences in recording practices from one area to another. An example might be whether more common items are photographed or not—typically less likely in East Anglia, with the primary motivation to increase recording capacity. There may be an omission of data that is seen as less important in a given recording context, such as ‘method of manufacture’, or even usually common attributes like ‘weight’. When such data are missing, the archaeological record is less complete and, as such, harder to study in a meaningful way across larger geographic areas.

Even less easy to detect, and requiring either deep (and therefore not easily replicated) knowledge of the long history of the database or extensive computational data exploration, are hidden particulars such as those linked to how spatial precision has been recorded. This is an important point, highlighting not only the need for database owners to log aspects of development (noted above), but also how the dataset has been collated and curated, and the decisions behind those choices. Here, we would like to emphasise that our research question and case studies are not limited to considering the outwardly negative aspects of human decision-making on the research value of archaeological data or, necessarily, how to mitigate it in terms of varying practices in data entry. For example, the addition of thousands of numismatic finds from the Iron Age and Roman period from external data dumps has substantially increased the size of the PAS database and added records that are more spatially precisely defined than many metal-detected finds. More neutrally, we wish to underline the necessity of capturing the rich process and paradata information involved so that it can enable and further enhance data *reuse—even* in ways that may be unexpected to its original creators. This speaks to the simple fact that the recording of archaeological artefacts—carried out by experts with often profound understanding of material culture, the contexts from which it is recovered and the evolving scholarship on the field—is also a case where human decision-making can (and does) bring enormous amounts of added value to bear.

Finally, cross-cutting technological solutions can be applied to various archaeological datasets. As we have argued elsewhere (cf. the Sampo model for opening archaeological data: [12, 28, 32, 33]), building easy-to-use ‘big data’ visualisation tools into open cultural heritage data services, so that anyone can investigate statistical patterns, would help reveal disparities and empower effective data reuse. It would then be easy to see, for example, if there are many more ‘badges’ compared to ‘pilgrim badges’ recorded in a certain county compared to others, which might indicate either an issue with recording practices or even reveal an interesting research question. Furthermore, with current and future technology it might be possible to monitor relative hit counts for different field selections in the data and alert the users of possible issues where, for example, one object type from one period might be over- or under-represented in the data of one county (or larger area) compared to others. Regarding data inconsistencies that can be defined as violations of explicit integrity constraints (e.g., ‘from date’ cannot be later than ‘to date’), data validation methods such as the shape-based SHACL already provide possibilities for detecting such errors when inputting data into a database.

This is clearly not an exhaustive list of FAIR-related challenges facing the creation of databases for recording archaeological finds. However, it might be regarded as the basis of many of the main issues to consider.

6 Conclusion

‘Good data in, good data out’! This article has highlighted the extent to which FAIR principles can be used to contextualise the impact of human decision-making on the research value of archaeological data, but also the limitations of data management tools and—by considering these aspects together—the overall complexities of ensuring high-quality data in archaeological datasets, taking the PAS database as an example.

As such, it advocates for database developers to work as closely as possible (as surely most do) with recorders and other primary users, but also (perhaps less commonly) for those building archaeological datasets to have a more holistic view of the needs of other potential end users, including those who might use the data in other contexts. The latter is trickier to account for, as it is harder to predict who these ‘others’ might be and justify the additional resources needed for such an approach. This said, there is a trajectory in the field of digital humanities to be more open-minded in this regard. From an end-user perspective, it is crucial to be transparent in the data production processes, such as what controlled vocabulary is used, how it is implemented, and how the data are constructed. Importantly, end users should have the information they need (regarding how a dataset is created and data inputted) to fully appreciate its biases and be open about that in the publication of their research. It seems an obvious point, but can be often overlooked.

Whilst the discussion here has focused upon archaeological databases, particularly the PAS database, the lessons learned are aimed at a wider sphere. No doubt, with new and advancing technology, it will be possible to better contextualise the impact of human decision-making on the research value of data. However, since the interpretation of data comes from the human mind, the challenge of creating 'good data' will remain.

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