

# The Impact of Human Decision-making on the Research Value of Archaeological Data

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'Good data in, good data out' is a well-known **adage**, though **usually** 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 just as likely inconsistencies in data recording. This is especially relevant when thinking about 'efficiencies' that recorders might make (i.e., to make their work easier) **and** what this might 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 paper will consider the impact of human decision-making on the research value of archaeological data, taking (as a case study) 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 as well as through a separate web application demonstrator (PASampo) that is being developed. The latter, in particular, enables ease-to-use visualization of the data to provide for an analytical evaluation of how data is inputted into the PAS data and, more significantly, how this data might be extracted by the researcher. Through a series of case studies exploring aspects of material culture, we will highlight how data quality is affected by human decision-making alongside aspects of the database framework. We will argue that this provides the basis of new learning 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 a database holds useful information for other people, but whether it can be easily extracted and exploited in full depends upon the application. For example, a numismatist might create a database of coin data for their use. **Since** it is obvious to them that all the items are coins, they might 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 **etc.**

The 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**, this data is 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 might seem obvious but are often overlooked and are, therefore, important 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 how** human decision-making in **developing archaeological** databases **and in** the recording process of archaeological finds, **in particular**, can substantially impact **their** research value.

These decisions are fundamentally important when aiming **to make** data 'Findable', 'Accessible', 'Interoperable' and 'Reusable' according to the widely accepted and used modern FAIR principles [49]<sup>1</sup>:

- *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.
- *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.

Crucial decisions to be made for creating FAIR data include:

- (1) What kind of functionalities and services are needed from the end user's point of view?
- (2) What (meta)data model [41, 50] to use for describing the artefacts, e.g., Dublin Core<sup>2</sup> or its derivatives, CIDOC CRM,<sup>3</sup> or its extensions, such as CRMarchaeo<sup>4</sup> and Nomisma<sup>5</sup>
- (3) What 'controlled vocabularies' [17], i.e., Knowledge Organization Systems<sup>6</sup> (KOS) [51], are used in populating the metadata element values (e.g., for object type, material, time/period, place of manufacture, findspot

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

<sup>2</sup>Dublin Core Metadata Initiative: <https://dublincore.org>

<sup>3</sup>CIDOC Conceptual Reference Model (CRM): <https://cidoc-crm.org>

<sup>4</sup>CRMarchaeo extension of CIDOC CRM: <https://www.cidoc-crm.org/crmarchaeo/home-3>

<sup>5</sup>Nomisma.org collaborative project: <https://nomisma.org>

<sup>6</sup>Encyclopedia of Knowledge Organization: <https://www.isko.org/cyclo/kos>

etc.).<sup>7</sup> **Several options are** available, such as the Getty Art & Architecture Thesaurus<sup>8</sup> for artefacts and PeriodO<sup>9</sup> for times and periods that were used **to harmonize** linked data thesauri in the pan-European ARIADNEplus infrastructure and portal.<sup>10</sup>

- (4) What practices are used for cataloguing the artefacts?<sup>11</sup> 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 [14] and express them etc. Cataloguing practices are especially well-developed for bibliographical records.<sup>12</sup>

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, but even then, quality issues arise, as the KOS are seldom complete and different users tend to make individual selections based on what seems logical to them, leading to low inter-annotator agreement [1]. The challenges are emphasised when **many** different users, especially those without a professional cataloguing/recording background, are inputting data, e.g., as in 'citizen science archaeology' [42], of which the PAS database (see below) is a good example.

Controlled language and drop-downs **for recording data** might be used to group and harmonize data, as well as limit the risk of human error,<sup>13</sup> **but** these tools are not fool-proof guarantees for capturing high-quality data. Similarly, training database users, as well as 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. Invariably, however, 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. For example, not completing certain fields perceived to be 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 in free-text fields (e.g., typos). 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.**

As a response to the development and adoption of digital technologies in cultural heritage management, the number of archaeological databases has proliferated in recent years [39]. With this has risen a greater need to capture and explore **paradata**, or information on the processes by which the data was collected [12]. While potentially relevant to all archaeological data, we focus our discussion in particular on large institutional databases, such as those published by national heritage agencies or schemes in many European countries (see e.g., [28, 29]). In terms of the impact of human decision-making, these typically possess some or all characteristics of:

- **Longevity:** being developed across multiple generations of technological solutions and carrying the mark of the specific motivations or constraints that each may impose.
- **Multi-user input:** being generated by many users with often different backgrounds, data management interests, scientific expertise and levels of training.

<sup>7</sup>Here we use 'controlled vocabularies', 'thesauri', 'ontologies' and 'typologies' as synonymous terms, to mean a structured language.

<sup>8</sup>Getty Art & Architecture Thesaurus: <https://www.getty.edu/research/tools/vocabularies/aat/>

<sup>9</sup>PeriodO gazetteer of periods for linking and visualizing data: <https://perio.do>

<sup>10</sup>Adriadne infrastructure: <https://ariadne-infrastructure.eu>

<sup>11</sup>E.g., [https://www.getty.edu/research/tools/vocabularies/cco\\_cdwa\\_for\\_museums.pdf](https://www.getty.edu/research/tools/vocabularies/cco_cdwa_for_museums.pdf)

<sup>12</sup>See e.g., <https://www.ala.org/pla/resources/tools/circulation-technical-services/cataloging-practices>

<sup>13</sup>Drop-downs on the PAS database include 'object type' for example, where users can only use the options available.

- **Diverse user audiences: being accessed across a long period of time by a wide variety of end-users with differing needs, many of which were likely never considered during the initial database design or development processes.**

Here, we take the Portable Antiquities Scheme (PAS) database<sup>14</sup> 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. This is not designed to be a criticism of the database, especially as the issues identified here are by no means unique to it, but it provides a good platform for this analysis for several reasons.

First, it is a large archaeological dataset, one of the largest **object databases** in Europe, of over **1 million records describing more than 1.7 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.) that have been discovered through hobby metal-detecting**. The data has been inputted by many people, 1175 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 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 etc); 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 particularly wide range of people across England and Wales, as well as internationally, who are interested in material culture. These include professionals in heritage management, academic researchers, hobby metal-detectorists and other archaeological citizen scientists, 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<sup>15</sup> language. Additionally, a web application based on the Sampo-UI<sup>16</sup> framework, known as PASampo, was used to explore and visualise the data **beyond that possible in the current PAS database**. Mainly for this application, a simple RDF<sup>17</sup> format conversion of the data was created.<sup>18</sup> 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 paper has been performed using multiple tools for exploring and analysing PAS data generated over **twenty** years.

The PAS database is currently undergoing a rebuild (2024–25), hence the lessons learnt here are likely to be useful in its development, and that of other archaeological databases also. **In the last ten years, several other European databases for recording public finds have been established**. Some, such as in Denmark<sup>19</sup> and Belgium,<sup>20</sup> **are particularly** dependent upon a citizen science approach [6, 47, 48]), and are driven by a recognition of the research value of public finds for advancing archaeological knowledge [40]. Even so, this paper offers a reminder to end users that data entry can cause biases, and it is useful for researchers to be aware of these when using any archaeological dataset.

<sup>14</sup>PAS database: <https://finds.org.uk/database>

<sup>15</sup>The R Project for Statistical Computing: <https://www.r-project.org>

<sup>16</sup>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 [29, 33].**

<sup>17</sup>Resource Description Framework (RDF): <https://www.w3.org/RDF/>

<sup>18</sup>**The data dump used for PASampo consists of 981 834 records downloaded on 3 March 2023**

<sup>19</sup>Digitale Metaldektorfund (DIME): <https://metaldetektorfund.dk/ny/>

<sup>20</sup>Metaaldetectie en Archeologie (MEDEA): <https://medea.weopendata.com>



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. 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

**In order** to interpret finds within their landscape context and to investigate their relationships to one another more generally, the precision of findspot data is of paramount importance. Metal-detected finds discovered by hobbyists are typically recovered from the ploughzone and, therefore, lack any stratigraphic context that aids their interpretation. **The wider** spatial and landscape contexts are therefore crucial in their study [5, 47]. PAS findspot data, like most British archaeological spatial data, is recorded using the Ordnance Survey National Grid Reference system (NGR<sup>21</sup>). In this system, the NGR indicates the location of a square within which the find was made, with longer NGRs giving greater precision. As seen in Fig. 1, most finds are given as 6-figure (within a **square 100m to a side**), 8-figure (10m), or 10-figure (1m) 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 percent of new finds were recorded to at least an 8-figure NGR, and 74 percent had at least a 10-figure NGR [23, p. 39]. Given that most 'portable antiquities' are from the plough-zone (93 percent 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.

Other factors impact on the character and quality of the data. Fig. 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.<sup>22</sup> Regions with no, or a very low density of, finds have been removed to even out statistical anomalies. The visualization shows clear regional variation across England and Wales. The Isle of Wight, **off** the south coast, and **most** of Wales, in the west, appear to have (on average) the most precise spatial data. Another major 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:

(a) *Recording and community relations.* The role of local Finds Liaison Officers (FLOs), who are primarily responsible for recording finds onto the database, is critical. The high spatial precision achieved on the Isle of Wight owes much to the work of a long-standing FLO (2003–20) who had good relations with the local detecting community. By 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

<sup>21</sup>National Grid Reference system: <https://epsg.io/27700>

<sup>22</sup>R spatstat homepage: <https://cran.r-project.org/web/packages/spatstat/>

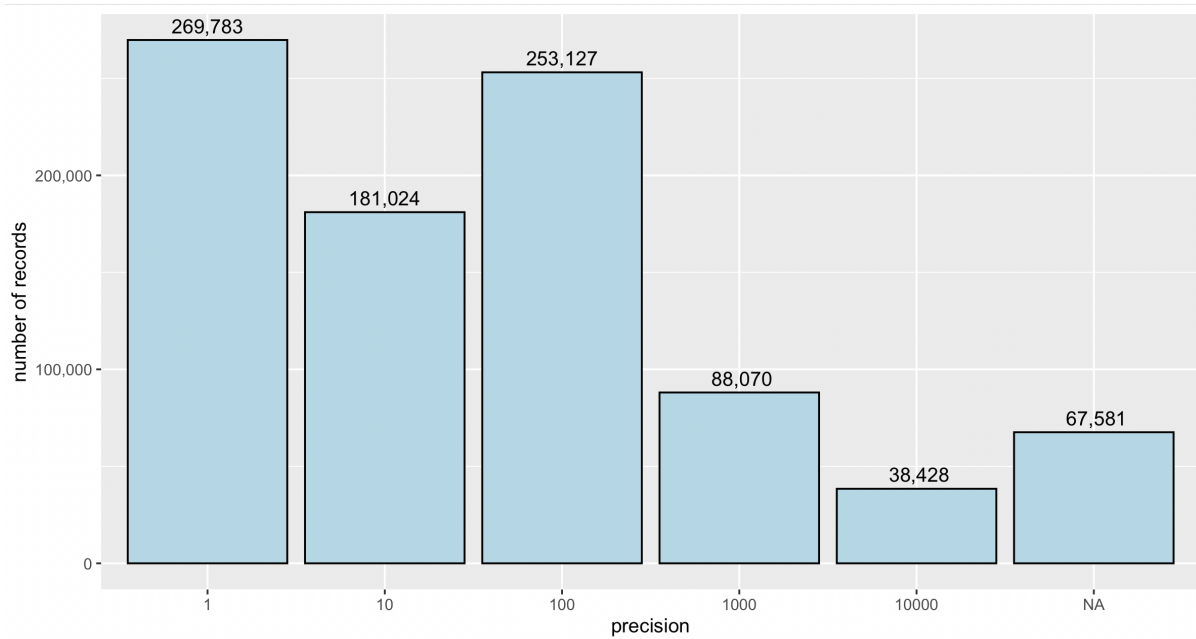


Fig. 1. PAS finds by NGR spatial precision. 1 = precise to 1 metre **square**. A small number (855) of finds with greater given precision than 1 were rolled into that category.

less willing to work with archaeologists highlights the importance of continuity and ongoing liaison between archaeologists and finder communities, thus resulting in more and higher quality records[37].

(b) *Reporting practice locally.* Hundreds of recorders logging information from thousands of finders over more than 20 years have contributed to the PAS database [3, 22]. The PAS was established on the back of long-term animosity between archaeologists and finder groups, [22, 44], **with suspicions towards collaboration with archaeologists lingering longer in some regions than in others**. This might be reflected in the difference in findspot precision between northern and southern England highlighted above, **as** (even now) **northern** FLOs note the reticence of **higher** proportions of finders **giving precise findpost 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., [9, 31]) – **so** become more familiar (and comfortable) with **finds** recording.

(c) *Data harmonization.* 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<sup>23</sup> (CCI, 37 844 records) and the Iron Age and Roman Coins of Wales<sup>24</sup> (IARCW, 52 812 records) databases, added in 2010. These projects are external to the PAS, yet amount to almost 10 per cent of all PAS records, digitized coins from existing archives, excavation reports and other sources. **Their inclusion is in itself 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.** It is **furthermore worth noting** that these data sources and recording practices

<sup>23</sup>Celtic Coin Index: <https://cci.arch.ox.ac.uk/pages/info>

<sup>24</sup>Iron Age and Roman Coins of Wales: <https://doi.org/10.5284/1000263>

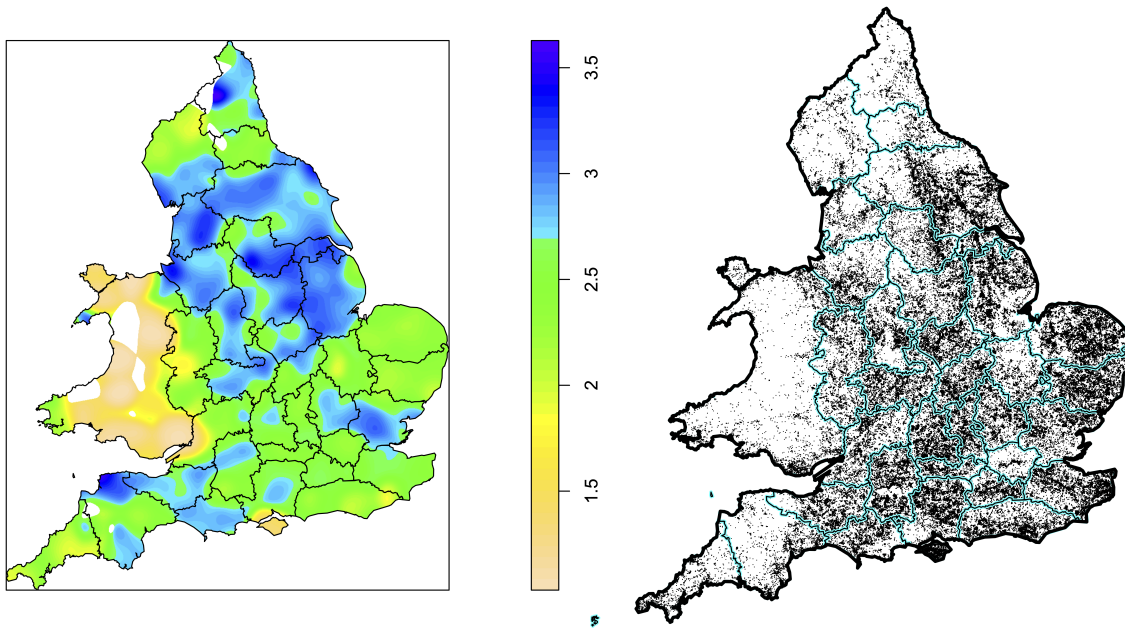


Fig. 2. Local average of findspot accuracy across England and Wales ( $\sigma = 10$  km) (**left**), and the distribution of findspots with coordinate values (954 161) (**right**). To assist with analysis and visualization, findspot accuracy has been translated so that the progression is not by an order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

vary 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, therefore, 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.

## 2.2 Impact of Educational Outreach

The decision to report a find is the penultimate 'stage' that an object must pass on its journey from deposition to becoming a database record [37, 38].<sup>25</sup> This is typically informed by an appreciation of the archaeological or other cultural heritage value of the find. Roman coins are the most commonly reported find type in the PAS database (297 747 items **on 29 June 2023**, representing 30 percent of all finds). Many detectorists do not always see great individual value in the small late Roman copper-alloy coins that are found in particularly large numbers, especially if they are poorly preserved. The significant archaeological and numismatic value of these 'grots', however, lies in the possibilities they offer in charting *en mass* hitherto poorly understood patterns in the Roman economy and money circulation. Certain **low**-denomination copper coins are also very rare in Britain, with only a few examples known. Specific issues of **these** coins can even be linked to particular events, such as

<sup>25</sup>See also the PAS Guide for Researchers: <https://finds.org.uk/research/advice>

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, 26, 45, 46].

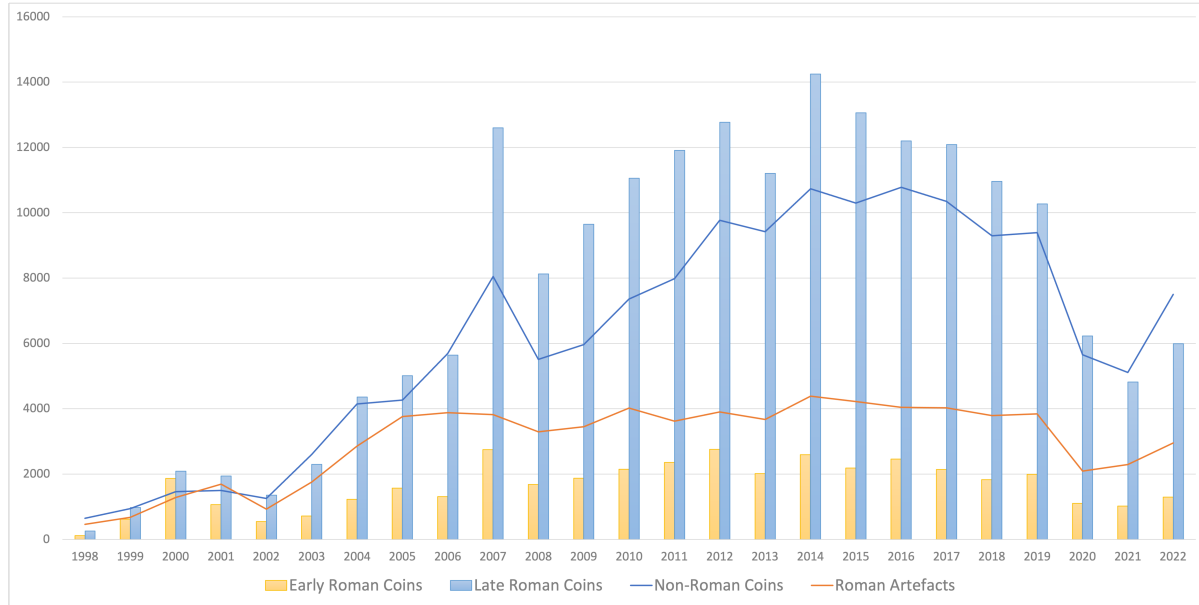


Fig. 3. Selection of different object types recorded in the PAS database 1998-2022. Data dumps from external projects have not been included in the figures.

The impact created by a short but concentrated educational outreach project on the PAS database can be most spectacularly seen 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 the county promoting the reporting of Roman 'grots' [27, pp. 3–7]. The results are seen in Fig. 3, which displays a significant peak in recorded late Roman coins, from c. AD 238, Reece period 12 [35, 36],<sup>26</sup> during that year. It is noteworthy that while this does not seem to have impacted upon the **annual numbers of new Roman 'non-coin' artefacts 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. While 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 large numbers 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, whereas for all other years (2003–20) 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, which significantly benefited archaeological and numismatic understanding of the past.

<sup>26</sup>Reece periods in PAS: <https://finds.org.uk/romancoins/reeceperiods>

The data, however, was not digested by the PAS database without leaving characteristic traces. **For example, 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. [19, p. 173]). 'Primary material' is one of the most consistently completed fields in the PAS database, with 98 percent of all records containing this information, **but in the case of Norfolk coin records made in 2007, the material field was left empty 95 percent of the time. Furthermore, most records also do not contain an image of the find.**

**Likewise, new records of old coin finds impacted the quality of location data.** In 85 percent of the Norfolk coin records **logged in 2007** with coordinate data (10 444) the NGR is given as a 10-figure reference (i.e., 1 m), but this is misleading as a closer examination shows that finds are **grouped** into only 1212 individual findspots. **This suggests 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 lumped together with 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. 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, 8]). 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 as a whole and has to 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. It is especially true for large cultural heritage databases (see also [28]), where, as in the examples above, data creation conventions may have varied across their operational lifetimes.

### 3 CASE STUDY B: OBJECT TYPES

This case study will illustrate the complexities of recording certain object types and the potential impact this has on data for research. Firstly, **coins are investigated.** 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 that also includes 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.**

#### 3.1 Coins as Standardised Objects

Coins are the most common finds **type recovered and reported by detectorists in many European countries, including England and Wales [30]. They have generally been mass-produced, are easy to classify and are easily recognisable by finders. In the PAS database, coin records currently constitute approximately 50 percent of all PAS records. Most are described according to internationally used standards, discussed below. Various drop-down menu options using controlled vocabularies are made available in the recording form, as well as 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, etc.**

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 can also name the ruler under which the coin was issued and the place where it was minted. These aspects, which (in most cases, except for 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 [16, 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.

Because of 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, etc.), geographic context (e.g., mint, region, findspot, etc.), issuing authority and other personal aspects (e.g., state, ruler, issuer, engraver, etc.), chronology (date), description (e.g., denomination, weight standard, as well as detailed descriptions of the obverse, the reverse and the edge, etc.), and condition (wear and completeness). Standardized references are also widely applied,<sup>27</sup> and digital projects, such as Nomisma.org, strive to provide stable concepts for recording coins within the principles of Linked Open Data, which can help to **harmonize 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 Fig. 4).** Material, **an attribute relevant to all archaeology**, is documented in 97.6 percent of cases, **but** weight in **only** 72 percent, and diameter in 63 percent. **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 can not 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, but for the medieval period, it was left out in 10 percent 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 **implicit**. **Reflecting the fact that it is an archaeological database the lack of information may also be the result of the condition of the object, as PAS 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. There are, **available to those using the PAS database**, separate numismatic guides and detailed recording schema 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 the recording of coins **with the PAS** usually follows certain established practices, searching for certain 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 difficult 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),

<sup>27</sup>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.

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., [15]). Sometimes harder to observe is the difference between **pre-depositional** damage and that made **later, once an item was lost in the ground**, such as by the plough. 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 process, not least as certain searches (like folded) will bring up hundreds of records, many of no relevance (such as coins showing figures with folded garments **rather than** folded coins).

Wear and completeness are also less frequently used values in the PAS coin entries, with information lacking in 34 percent of the cases. The information of completeness is 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 coins that are simply extremely worn or misstruck, 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. **Importantly**, for already well-standardized objects like coins, it would further minimize the risk of definitions open to interpretation.





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

### 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, 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 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 hard for the researcher to locate if not recorded consistently.**

The PAS 'finds guide' for 'pilgrim badges'<sup>28</sup> advises database users to record medieval pilgrim badges as a 'PILGRIM BADGE' (Fig. 7) in the 'object type' drop-down, as opposed to 'BADGE' (Fig. 8), which should be used for 'secular' and 'livery' badges<sup>29</sup>. **In fact, this taxonomy might be too simplistic since there are other 'religious badges' that might not have all the characteristics of a pilgrim badge such as a visual focus on a saint's cult representation.** The essential point here is that **categorical typologies** are imperfect models for many items of material culture [11].

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 that this 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 their '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 [21, 24]. Similarly, it has also been argued that 'profane' badges, so usually depicting a phallus and/or vulva, or sex scenes, might have religious connotations [7]. Whatever the theoretical complexities determining whether a badge is a pilgrim badge or not (see [21, 43]), the

<sup>28</sup>Pilgrim Badges in PAS: <https://finds.org.uk/counties/findsrecordingguides/pilgrim-badges/>

<sup>29</sup>Badges in PAS: <https://finds.org.uk/counties/findsrecordingguides/badges/>



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

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

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, it is apparent that this guidance is not always followed, creating issues for end users of this data.



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

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: Fig. 9), **for example**, 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. In the case of another badge, this time from Leckhampstead, Buckinghamshire (BUC-6E8E43), the image is hard to make out, although 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 not recorded **in the 'object type'** as **such**. These include one showing the



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

Annunciation, from Glemsford, Suffolk (SF-527947: Fig. 10), and another of the unofficial cult of **King Henry VI of England (1421–71)**, found at Wakefield, South Yorkshire (SWYOR-E2D028). Here then, it would seem human error' has resulted in **pilgrim badges being recorded as badges**.



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

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 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. That said, it is like a pilgrim badge in terms of its composition and form, highlighting the limitations of the controlled vocabulary used.

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**



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

**databases'** filter function then enables certain **attributes** to be **targeted** (e.g., types of material composition). However, with more and more data being added to the PAS database, it is becoming harder for researchers to find items if divorced from where they might expect to see them.

Most of the 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. Also, 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 particularly common in Lincolnshire (e.g., NLM-BECE1A, NLM-02E8A7: Fig. 11 and LIN-4A9334), and therefore **have been** suggested to be associated with the local cult centre of Ketsby [20]. **Somewhat incorrectly, they** have been traditionally recorded as pilgrim badges though they are certainly pendants.

Some badges, often continental, have loops, which distinguish 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 certainly 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: Fig. 12 and LANCUM-0AB780), and even Canterbury bells (KENT-EC8680). In short, the items recorded as pilgrim badges show inconsistency in the use of that term, which makes the database harder to use for researchers and others (Fig. 6).

#### 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 described in the above case studies**, include various data validation techniques. For example, recent advances in the context of Linked Data include Shapes Constraint Language (SHACL)<sup>30</sup> and Shape Expression Language (ShEx),<sup>31</sup>

<sup>30</sup>Shapes Constraint Language (SHACL): <https://www.w3.org/TR/shacl/>

<sup>31</sup>Shape Expression Language (ShEx): <https://shex.io>



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)

machine-processable languages for validating data against a set of conditions [18]. These integrity constraints specify the 'shape' that the data has to conform to for the data to be semantically valid. Based on these languages, there exists 'validation software'<sup>32</sup> 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.

As a case study, a small-scale data validation experiment has been made, using the PAS dataset within PASampo, focusing on **periods and dates**. The PAS uses a broad period classification for finds, following FISH (Forum on Information Standards in Heritage) vocabularies, which includes (chronological) date ranges for 'archaeological periods'.<sup>33</sup> In addition, the PAS records individual finds (i.e., unique records with the PAS database, replicated with PASampo) with a date range ('from date' - 'to date') which allows for more precise temporal recording

<sup>32</sup>E.g. Apache Jena SHACL: <https://jena.apache.org/documentation/shacl/>

<sup>33</sup>FISH thesauri: <https://www.heritage-standards.org.uk>

than using the broad period classification. To interrogate these data, a SHACL shape was created, 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' that is 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 2000 errors of this type, including, an Iron Age quarter *stater* (KENT-CC89C1) recorded with the date range AD 80–60 in error; the correct dating is 80–60 BC, as in the textual description of the find it where is stated 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 violations are caused by human error, and therefore this tool can help ensure the integrity of the data and its future value for researchers.

Nonetheless, 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, it was found some 50 000 Roman coins 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 inconstancy. 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 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 other error types 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 that were found in the case study could have been prevented already 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 **below** (Fig. 13).

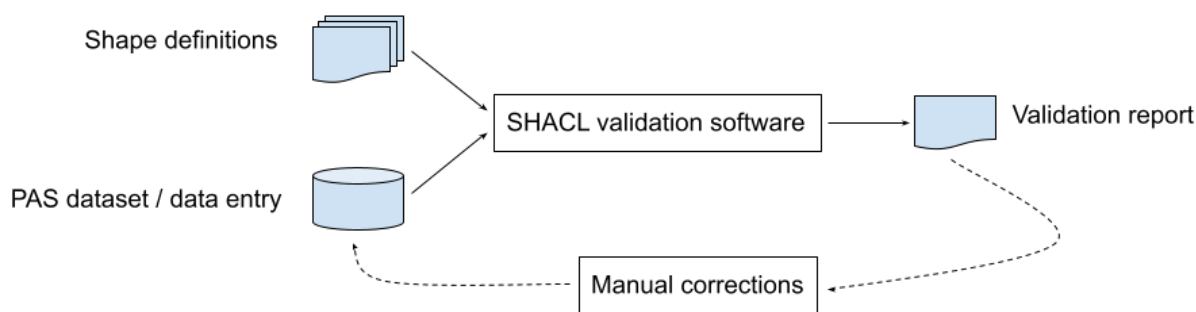


Fig. 13. Proposed SHACL validation workflow for the PAS dataset, either integrated in the data entry phase or as a separate data consistency check by the database owner

## 5 DISCUSSION

**Controlled** vocabularies (such as thesauri, ontologies, etc.) are essential tools for enhancing data quality, not only when inputting data, but also for improving precision and recall when mining or searching databases. As such, it is imperative that recorders use terms from a predetermined list of drop-downs for key data following industry-agreed vocabularies. In general terms, the PAS database follows FISH vocabularies, though it has 'flattened' and adjusted the FISH thesaurus (i.e. its hierarchy is not respected in the 'object-type' drop-down, and **some** new terms have been added). 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 means that researchers and other end users can refer to this to understand these terms and their relationship to one 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 needed by developers to implement controlled vocabularies (versus free text entry) within a database, the case studies above show how drop-downs can be used differently by multiple users, even in the case where fields are mandatory. This differing usage is sometimes likely to reflect the fundamental epistemological issue that controlled vocabularies, like all KOS, are imperfect at modelling the real world and certainly cannot be taken as neutral representations of it (e.g., [10]). Highlighted above, concerning pilgrim and other badges, was the issue of how recorders might distinguish between **object types**, based not only on their understanding of material culture but also on how such theoretical concepts fit within the medieval worldview. This might be a particularly **critical** issue for archaeology and cultural heritage studies, subjects that deal with highly complex contingent phenomena and processes where our understanding and research are continually evolving, **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 original inception and delivery in 2003 [32].

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 end up using 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 the data themselves and, therefore, might not fully appreciate the nuances of the decisions they make. With PAS numismatic data, as a case in point, it is clear that some attributes of a coin are valued less by some recorders than others, even when a drop-down or choice of another field exists. It is likely that this is 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 [25]. Invariably, where data is 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 sorts 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 recording of certain object types (for instance Roman 'grots'). 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 is missing, the archaeological record is less complete and, as such, harder to study across larger



geographic areas in a meaningful way. 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.

Minor reworking of used vocabularies might help recorders produce better data, but in practice, this can be difficult to manage retrospectively – especially if thousands of finds would need to be re-classified. **As the authors have argued elsewhere (cf. the Sampo model for opening archaeological data: [13, 29, 33, 34]), building easy-to-use data visualization 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 the challenges facing the creation of databases for the recording of archaeological finds, but might be regarded as the basis of the main issues to consider.**

## 6 CONCLUSION

**'Good data in, good data out!' This paper has highlighted 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 also justify the additional resources needed for such an approach; though there is a trajectory in the field of digital humanities to be more open-minded in this regard. Crucial, from an end-user perspective, is being transparent in **the data production processes, such as** what controlled vocabularies are used, how they are implemented and how **the** data is constructed. **Ideally,** end users **should** have the information they need (in terms of how a dataset is created and data inputted) to fully appreciate its biases and make as full use as possible of it for their research.

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

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