

# Linked Data and Cultural Heritage: A Systematic Review of Participation, Collaboration, and Motivation

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The cultural heritage sector has traditionally been concerned with sharing resources and furthering human knowledge, with particular interest to the issues associated with metadata and interoperability, especially when it comes to the use of technology. These goals and interests in the cultural heritage sector are natural alignments with those of linked data; hence, there has been an increasing interest in the application of linked data in this sector. This article studies the implementation of linked data in the cultural heritage sector, through a systematic literature review of case studies of linked data implementation projects in this sector. The results reflect on the parties involved, the level of collaboration, and the motivation behind these projects. The study suggests that universities and national institutions were the main players in implementing such technologies in the cultural heritage sector, suggesting that there may be some barriers preventing smaller GLAM institutions from implementing linked data projects. The results further suggest that many linked data projects in this sector were primarily exploratory projects, and often performed in a collaborative manner. They further indicate that the most common motivating factors behind these projects were research needs, a desire to contribute to linked data as a movement, and other specific user needs. Reflecting on this systematic literature review, this article makes a set of recommendations for future work to increase the use of linked data in the cultural heritage sector and to remove barriers to adoption.

CCS Concepts: • **Applied computing** → *Computers in other domains*; • **Information systems** → *World Wide Web; Web data description languages; Information systems applications*;

Additional Key Words and Phrases: Linked data, cultural heritage, semantic web, GLAM

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## 1 INTRODUCTION

Linked data and semantic web technologies have been the subject of much discussion in the cultural heritage sector in recent years. The term “the semantic web” was coined by Tim Berners-Lee and describes a web of connected data—as opposed to the Web, which is a web of connected documents which is created through the

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use of common metadata standards [1]. Semantic Web technologies are a means for providing a machine-readable data structure and also facilitate information integration from various sources which are built using the same underlying technologies. Linked data refers to the publication of data using these frameworks so that they can be accessed through semantic queries, with the aim of data to be linked, shared and reused across systems. Linked data is closely linked to the principles of open data, through movements such as 5-star Open Data (<https://5stardata.info/en/>), which recommends the open publication of linked datasets as the highest level of open data [2].

The potential benefits of linked data technologies have often been described in grand terms: it has been claimed that the semantic web “can assist the evolution of human knowledge as a whole by “[opening] up the knowledge and workings of humankind to meaningful analysis by software agents, providing a new class of tools by which we can live, work and learn together” [2]. One claimed benefit of the semantic web is that it may make the internet a more “collaborative space” [3].

The much-discussed potential benefits of linked data have led to the rise of significant hype around the topic. In 2015, Gartner’s Hype Cycle put linked data in the “trough of disillusionment” and predicted that the “plateau of productivity” would be reached in the following 5 to 10 years [4]. As linked data makes its way toward widespread adoption, the ideals which underpin it are of particular interest.

The cultural heritage sector (here taken to refer to a sector concerned with tangible cultural heritage; namely galleries, libraries, archives and museums— also known as GLAM organisations, universities, and certain public and private organisations) has traditionally been concerned with sharing resources and furthering human knowledge. As these goals appear to align with those of linked data, it follows that this technology could be of great use to those working in the cultural heritage sector. These technologies may also be of particular interest to the cultural heritage sector as the issue of interoperability of metadata between institutions has been noted as a focus in this sector [5].

Linked data holds the potential to improve interoperability and information sharing in the cultural heritage sector, and there is already much being done to create standards and platforms to realise this potential. A number of studies published in recent years have applied the method of systematic literature review to study linked data applications. This method has been applied to the assessment of recommender systems which use linked data [6], the use of tools for the creation and publication of linked data datasets [7] the assessment of data quality among published linked data [8], and the increasing use of linked data in the areas of medical research [9] and education [10]. A recent study [11] assessed best practices for publishing linked data by way of a systematic review. As part of this study, the authors considered the motivation behind the publishing of linked data in various domains, including the publication of metadata for cultural heritage artefacts. This study found that the publication of cultural heritage linked data was motivated by the benefits of uniformity, de-referenceability, integrability, and standard practices. Having said that, the data for the area of cultural heritage in their paper was limited to only two studies.

Despite the relevance of linked data to cultural heritage, and the clear potential benefits, there is no systematic literature review to date studying the application of these technologies in this sector. This highlights the need for a systematic study of the current uses of linked data in cultural heritage, in order to learn about the institutions and projects which have taken advantage of these technologies, the reasons for their interest, and their motivations. To this end, this article studies the current state of linked data implementation in the cultural heritage sector through a systematic review of case studies linked data implementation projects in the cultural heritage sector. This study is motivated by the following three research questions:

RQ1: What types of organisations are involved in the implementation of linked data projects?

RQ2: To what extent do linked data projects involve collaboration between institutions?

RQ3: What are the motivating factors which drive cultural heritage organisations to undertake linked data projects?

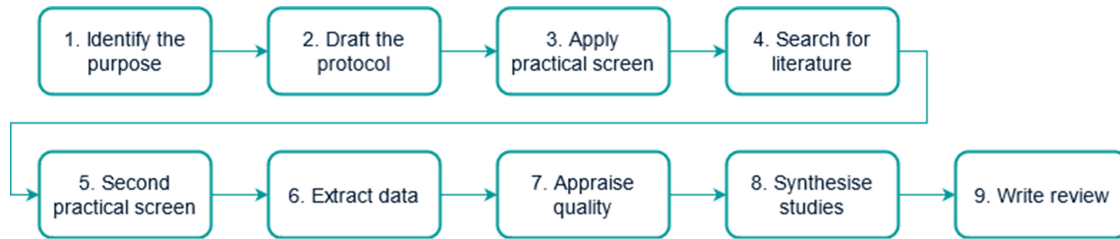


Fig. 1. Method of present literature review, adapted from Okoli [12].

The systematic literature review presented in this article seeks to ascertain whether the ideals of collaboration and data sharing for the improvement of human knowledge are being upheld, and whether they are the primary motivating factor, to the practitioners who are currently implementing linked data projects in cultural heritage. This review will also assess what types of organisations most frequently involved in these projects, whether these projects are being conducted in a collaborative environment, and what motivating factors drive them. Finally, this article provides a set of recommendations for future work in this area. Based on this, we provide a set of recommendations for future work that may be required to increase linked data adoption in this sector and to ensure that cultural heritage professionals and organisations are able to use this technology to its full potential.

## 2 METHOD

The next sections provide instructions on how to insert figures, tables, and equations in your document.

This article seeks to answer the research questions through a systematic literature review of published case studies on the application and implementation of linked data in cultural heritage and GLAM sectors.

This review was conducted following a process adopted from Okoli [12], which proposes eight steps to the review process. Our adapted nine step method is depicted in Figure 1, and explained in the following:

1. *Identify the Purpose.* This involved the drafting and revision of the study’s goals, including the creation of the three research questions which guide the study.
2. *Draft the Protocol and Train the Team.* As this study was conducted by a single reviewer, training a team was not necessary. A protocol was written to outline the proposed method of review.
3. *Apply Practical Screen.* Okoli also terms this “screening for inclusion” [12]. This involved the creation of inclusion criteria, which are described below.
4. *Search for Literature.* This step involves both the search for literature and the detailed documentation of the search process, the method of which is discussed below.
5. *Apply Second Practical Screen.* The practical screen criteria were applied for a second time to study abstracts following the search for literature in order to reduce the number of irrelevant titles included for quality appraisal.
6. *Extract Data.* Data extraction was conducted systematically through searches for keywords and close reading of all selected material, from which data relating to each research question was gathered.
7. *Appraise Quality.* This is also referred to as ‘screening for exclusion’ [12]. Quality appraisal for this review was largely based around the criteria of case study research, as is discussed in greater detail below.
8. *Synthesise Studies.* This involved the analysis of the extracted data from the final accepted literature, the results of which are detailed in the next section.
9. *Write the Review.*

The following provides a detailed description of the method by which Seps 3 to 6 were conducted for the purposes of this study. The other five steps (1, 2, 7, 8, and 9) are believed to be self-explanatory.

For the first of these steps (Step 3), a list of inclusion criteria was created as follows:

- (1) The studies included must describe projects to implement linked data or semantic web technologies.
- (2) The studies included must describe projects in the cultural heritage sector: this includes galleries, libraries, archives, and museums (GLAM institutions) and private or public organisations which are involved in cultural heritage, such as university faculties with relevant areas of study or government bodies with a mandate to protect or to work with heritage materials.
- (3) The studies included must be case studies; Case studies are specifically chosen as they describe real world projects as opposed to experimental or theoretical works. Multiple case studies were allowed only in the event that each individual case included sufficient detail to meet the requirements of a case study, as are defined in (IV).
- (4) Finally, multiple studies which described the same project(s) were not included. For instance, multiple studies discussing the development of the Europeana platform were found in the literature search. Such multiple studies often provide a repetitive description of key elements of these— often large—projects. For this reason, only one, the most recent publication, was included as this was believed to be sufficient to answer the research questions in relation to that particular project.

As regards the search for literature (Step 4), studies were gathered for this review by searching several databases, including Scopus, Web of Science, IEEEExplore, EBSCO’s Library and Information Science Abstracts, Proquest’s Library and Information Science Collection and Education Collection. Further texts were gathered from the *Journal on Computing and Cultural Heritage* and through citation chaining or “backward search” [12] from collected texts and related literature. Broad search terms were chosen in order to capture a wide range of articles relating to linked data and cultural heritage. The search string used was “(linked data OR semantic web) AND case study AND cultural heritage”. This search string was used to search all metadata fields, including abstract, keywords, and full text. This was only changed when searching the *Journal of Computing and Cultural Heritage*, during which the term “cultural heritage” was removed because it was considered redundant, given the topic of the journal. This search resulted in 610 works, of which 498 were accepted for review after duplicate titles were removed.

A second application of the practical screen criteria to study abstracts took place after the search for literature (Step 5), a slight adaptation of Okoli’s method as shown in Figure 1. The reviewer read the abstract of each article returned by the search, and removed any articles which did not meet the practical screen criteria. The search for literature had initially returned a high number of irrelevant texts, and the application of these criteria to the collected literature significantly reduced this number. This process reduced the number of articles taken for review considerably to 94 texts.

Data relevant to each research question was then systematically extracted from each article through a thorough reading of each study (Step 6). Each article was scanned for keywords relevant to our research questions, including “collaborate”, “motivation”, “incentive”, and “partner”, or closely relevant keywords and topics. Any potentially relevant information regarding our research questions were carefully examined, extracted, compiled, and coded.

Following the extraction of this data, the quality of each study was appraised (Step 6). A key factor in appraising the literature for quality was whether the studies met the criteria of case study research. Case study research is often criticised for its perceived lack of rigour [13] and, even among case study researchers, there is little agreement over the necessary criteria of case study research [14]. This lack of consensus complicated the process of choosing a definition by which to assess quality. As Robert Yin’s work has been influential in case research and provides a thorough definition of case study criteria, this work was selected as the basis for the quality screen. Yin suggests that there are five characteristics which comprise an exemplary case study [15]: (1) The case study must be significant; (2) the case study must be complete; (3) the case study must consider alternative

perspectives; (4) the case study must display sufficient evidence; and (5) the case study must be composed in an engaging manner.

Given that many of these texts were all case studies [16, 17, 18, 19], which were therefore focussed on describing the outcomes of their project rather than placing their findings in a wider context, the consideration of alternative perspectives was not deemed to be a key assessment criterion for this study, as the primary concern of these studies was exploration and description of individual cases rather than assessment of wider contexts. The manner of composition was also not considered a disqualifying factor as this varied significantly across the literature and proved difficult to apply to conference papers and journal articles equally. Thus, the three characteristics by which the quality assessment was carried out in our study were *significance*, *completeness*, and *sufficiency of evidence*.

*Significance* was taken as the significance to the area of study, i.e., whether the study presented a valuable case to the area of linked data in cultural heritage. *Completeness* was a factor by which several studies were excluded, as several described a project but did not describe the background, context, or details of implementation, or did not include sufficient detail to answer one or more of the research questions at hand. Sufficiency of evidence also disqualified several studies, as some texts gathered did not include any evaluation of the project or description of outcomes. Following the exclusion of texts which did not meet these criteria, 42 studies remained. Each of these studies was on a distinct project, with the exception of one paper, which discussed two [20], which makes a total of 43 projects to be studied. A full list of studies, including the tags and information associated with each research question, can be found in Appendix A.

These studies were published in a variety of journals and conference proceedings with little concentration in any one publication. The highest concentration was in the *International Journal on Digital Libraries*, from which seven articles were taken. *CEUR Workshop Proceedings*, the *Journal of Library Metadata*, the *Journal on Computing and Cultural Heritage*, and *Library Hi Tech* each provided two texts. From the remaining journals and publications, only one text was taken in each case. The full distribution among journals can be found in Table 1. The final step in the process was to analyse the extracted data, the findings of which are detailed in the next section.

### 3 FINDINGS

The final 42 papers included in this literature review were all published between the years 2009 and 2018. This shows the interest in linked data research in the cultural heritage sector started around 10 years ago. This could be due to the fact that linked data research itself started its maturing process not far before that date. The distribution across years of publication is depicted in Figure 2. Publication of case studies on linked data in the cultural heritage sector appears to have peaked in 2015, suggesting that these projects were primarily carried out in the years preceding, and less so in the following years. In the years following 2015, there have been a smaller number of case studies in this areas, which may reflect the relative limited success of the implementation of these projects, or the lesser interest or attention to these studies following the linked data hype, or the period where linked data and semantic web, themselves, were amongst popular topics in computer science and related areas.

A Scopus search on “linked data” OR “semantic web” shows that the overall popularity of linked data and semantic web studies peaked in 2010, and while the overall number of published studies on these two topics started a downward trend since 2010, between 2014 and 2015 the topic gained a relative popularity, before it started continuing its overall downward trend after 2015. The same search conducted in the Web of Science shows similar higher numbers of publications in 2008 and again in 2015, before a similar downward trend from 2015. In fact, the relative peak in 2015 could, to a great degree, be associated with the study of application of linked data and semantic web in other domains, such as cultural heritage.

Table 1. Distribution of the Final Set of Selected Studies Among Publication Sources

Source	Number of Records
International Journal on Digital Libraries	7
Library Hi Tech	2
Journal of Library Metadata	2
Journal on Computing and Cultural Heritage	2
CEUR Workshop Proceedings (conference)	2
Cataloging & Classification Quarterly	1
Journal of Web Librarianship	1
Information Technology and Libraries	1
Journal of Information Science	1
Aslib Proceedings	1
Library Review	1
Frontiers in Artificial Intelligence and Applications	1
Visual Resources Association Bulletin	1
Journal of Documentation.	1
International Journal of Web Engineering and Technology	1
Communications in Computer and Information Science	1
Digital Scholarship in the Humanities	1
2017 International Conference on Engineering, Technology and Innovation (ICE/ITMC) (2017)	1
2015 11th International Conference on Signal-Image Technology Internet-Based Systems (SITIS) (conference)	1
2015 4th International Symposium on Emerging Trends and Technologies in Libraries and Information Services (conference)	1
2015 Digital Heritage (conference)	1
2013 Digital Heritage International Congress (DigitalHeritage) (conference)	1
2009 IEEE International Conference on Semantic Computing (conference)	1
WWW'12 - Proceedings of the 21st Annual Conference on World Wide Web Companion (conference)	1
Lecture Notes in Computer Science (book series)	1
Semantic Technology (conference)	1
Knowledge Engineering and Knowledge Management (Book)	1
The Semantic Web - ISWC 2015 14th International Semantic Web Conference	1
Museums and the Web 2009 (conference)	1
Judaica Librarianship	1
Program	1
Journal of the American Society for Information Science and Technology	1

### 3.1 Key Players

To address our first research questions (RQ1), the participating organisations in each project were examined. The majority of these studies involved multiple participating bodies (this is discussed further below with regard to RQ2); therefore, it is often difficult to ascertain which body instigated the project. It is, however, possible to see clear trends in the types of organisations which frequently participate in the implementation of linked data in cultural heritage projects.



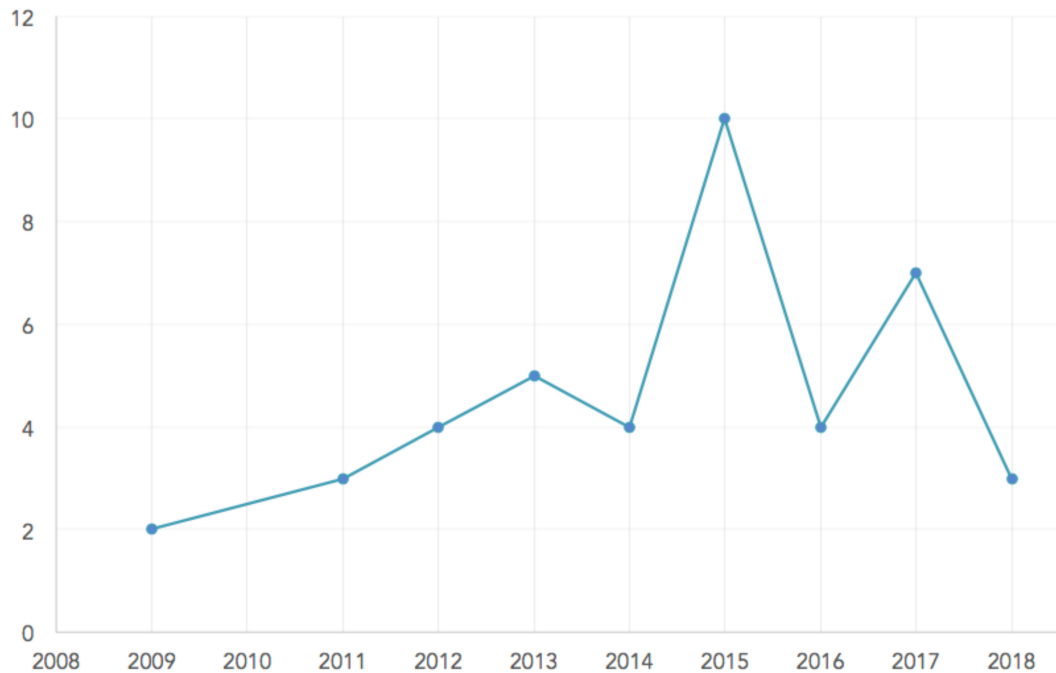


Fig. 2. Year of publication of accepted studies (number of papers).

The study reveals that university libraries were involved in 11 projects, and other departments within universities were involved in 24. In Figure 3 below, the category of University represents the participating university departments which were not libraries. Universities were the most highly represented organisation type in this study. Nine National GLAM organisations were involved in the collected studies: the Biblioteca Nacional de España [21], the British National Archives [22], the National Audiovisual Archive of Finland [23], the National Library of Finland [24], the National Library of Latvia [25], the Royal Library of Belgium, [26], Bibliotheque Nationale de France [27], the National Library of Israel [28], and the National Library of Ireland [29]. This was the second most frequently represented organisation type.

There was significant variation among the rest of the bodies involved, which included six instances of involvement from museums, three repositories, and three non-university research bodies. Seven projects showed some involvement from government bodies. Collective organisations were also represented, with one instance each of a consortium, a society, and an association. The European Union was directly involved (beyond funding) in two projects [30, 31]. Three projects involved non-governmental public bodies [27, 32, 33] and five involved private companies [23, 27, 32, 34, 35]. Public libraries were represented in one case, in which two public libraries contributed [23]. Two projects involved private or special libraries [36, 33], and one involved a private art foundation [37].

There is clearly variety in the bodies participating in these projects. However, 35 out of 42 projects involved a university, indicating that universities are leading the way in linked data implementation. Figure 3 presents the distribution of key players in the use of Linked Data in Cultural Heritage literature.

### 3.2 Collaboration

To study the second research question (RQ2), the studies were divided into general categories of collaborative and non-collaborative projects. This proved difficult in some instances, as a number of studies do not directly

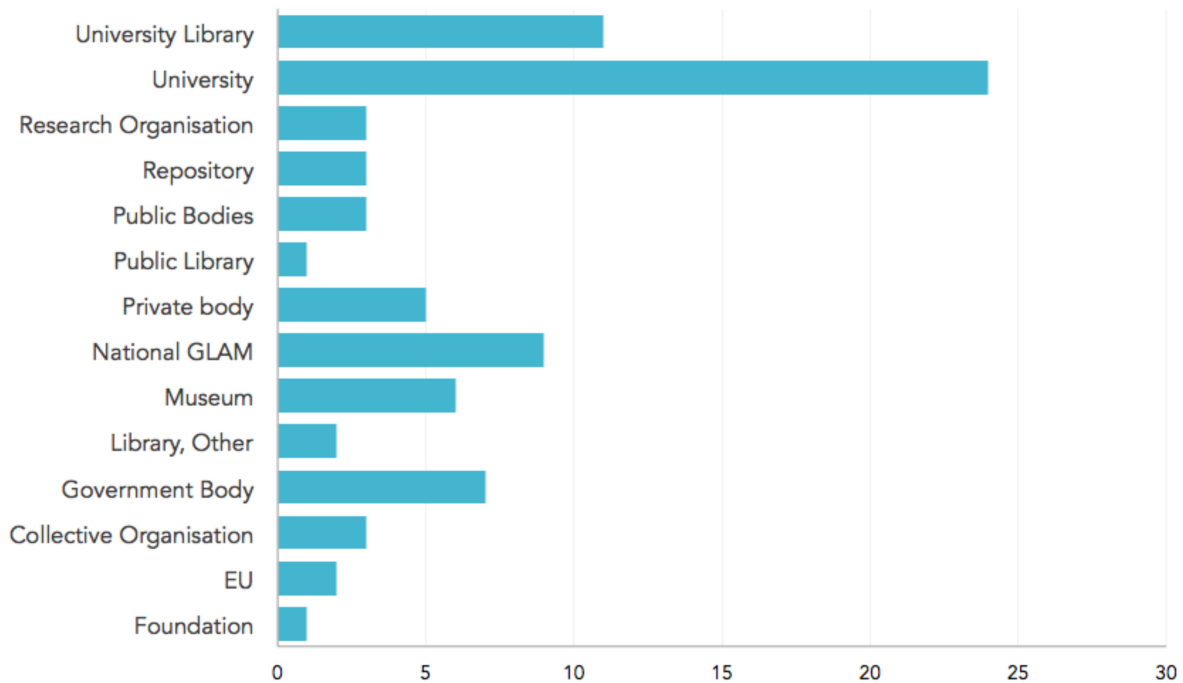


Fig. 3. Types of participating bodies involved in linked data projects in the cultural heritage sector.

state the participants involved in their projects. The level of collaboration was determined based on the naming of participants in the text of the literature reviewed. Article text, in some cases, had to be supplemented with information from the authors' acknowledgements or from further online searching in order to supply the detail necessary to answer this question. The breakdown of studies into the categories of collaborative-stated (in which the collaboration is clearly outlined completely or in part within the text), collaborative-not-stated (in which the collaboration was confirmed by external information), and non-collaborative (in which no evidence of collaboration was found) can be seen in Figure 4.

The categories of collaborative-stated and -not stated make up 31 of 42 total studies, indicating that collaboration does play a central role in most linked data projects in the cultural heritage sector. However, the emphasis placed on collaboration in linking data renders the existence of the nine non-collaborative studies somewhat surprising.

There were several studies included which showed exceptionally high levels of collaboration. The project described in Hyvönen et al. [32] involved a consortium of 38 companies and public organisations, as well as collaboration between government, university, and private and public organisations. The project, studied by Hypén and Mäkelä [23], involved collaboration across borders, as multiple Finnish organisations worked with a Swedish public library. Several further studies [27, 28, 38, 39] also included similar high numbers of organisations involved.

### 3.3 Motivating Factors

With regard to the third research question (RQ3), we examined the motivations behind these projects. In a recent study on the application of linked data in various domains, Feitosa et al. [11] found that the publication of cultural heritage metadata was motivated by the benefits of uniformity, de-referenceability, integrability, and standard



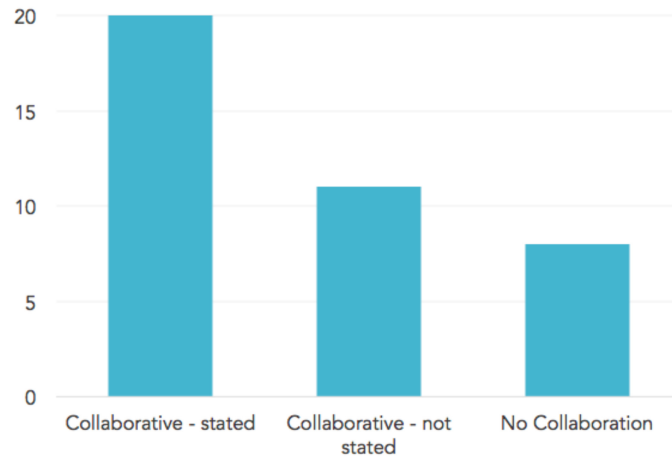


Fig. 4. Collaboration in linked data projects in cultural heritage sector.

practices. Their study covered linked data projects in a number of different sectors, and the data for the area of cultural heritage was limited to only two studies.

In our study, the majority of linked data case studies include some description of the aims of their project, or the aims are revealed through the priorities which guide the project. From the literature surveyed, eight themes emerged in these indications of motivation: *exploration of linked data*, *discoverability*, *education*, *GLAM needs*, *interoperability*, *preservation*, *research needs*, and *user needs*. These themes are detailed below.

**3.3.1 Exploration of LD.** Many studies which were exploratory in nature indicated that this factor made up part of their motivation. These studies were exploratory in the sense that they were generally concerned with exploring the possible uses or trialling new methods of using linked data in cultural heritage sector. This theme includes those that wished to develop tools or guidelines in order to aid others in implementing similar projects [17, 20, 37]. This also includes those that take on projects not due to a particular institutional goal, but in order to participate in, or explore the benefits of, the linked data movement [19, 40].

**3.3.2 Discoverability.** This theme was taken in articles which value linked data for its ability to make their collections visible or to bring attention to their institution. This includes studies which centred around a particular collection, rather than being focused primarily on the technology [17, 27, 33].

**3.3.3 Education.** These studies are driven, partially or wholly, by the desire to fulfil an educational need: to provide a resource for students to better study their collections for the purposes of teaching and learning rather than for research purposes [34, 40, 42]. This was closely related to research needs and user needs but differs in that the purposes of teaching and learning were explicitly stated by the authors.

**3.3.4 GLAM needs.** This theme was found infrequently and describes studies that were in some way motivated by the needs of GLAM institutions. Linked data was chosen in these cases in order to reduce operational costs and avoid the duplication of work [21, 23, 32]. These projects viewed linked data as a tool to improve efficiency within their organisations or industries.

**3.3.5 Interoperability.** This is a benefit of linked data which is frequently praised, but did not appear frequently as a motivating factor in these studies. This factor relates to the ability of linked data to link disparate collections and prevent information silos within institutions. This is related to both discoverability and GLAM needs. This was taken as a separate theme as it was mentioned explicitly by these studies, and primarily reveals

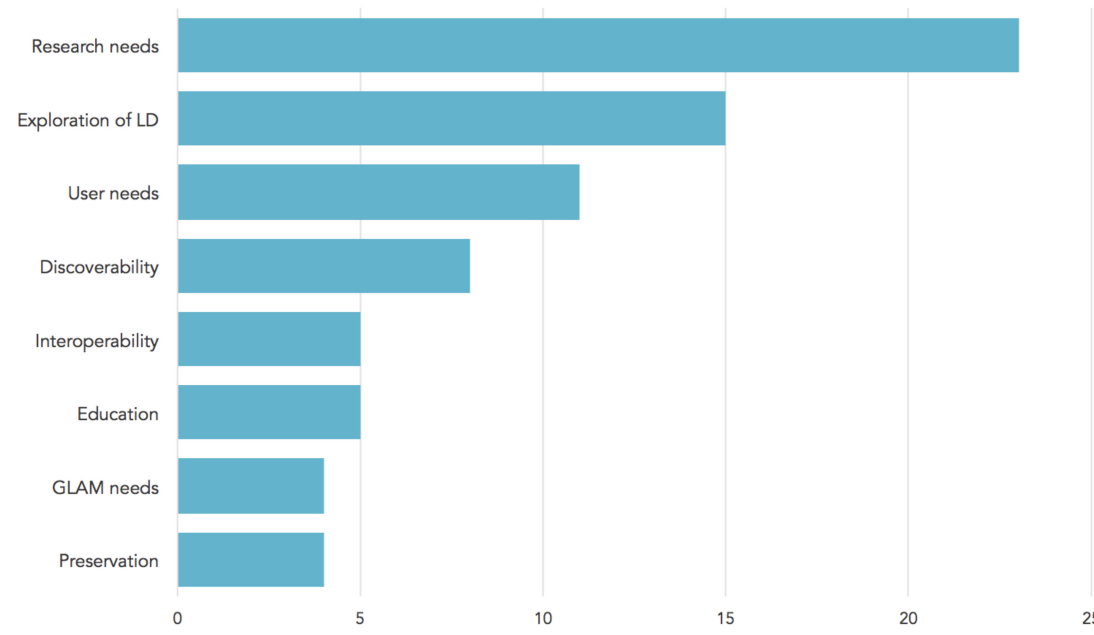


Fig. 5. Motivational factors behind linked data projects in cultural heritage sector.

an awareness of and alignment with the discourse that surrounds linked data. This aspect was mentioned by Valentino [17], Niang et al. [43], Tallerås et al. [44], Winer [28], de Boer et al. [45], and Binding and Tudhope [46].

**3.3.6 Preservation.** This was also mentioned in only a few studies. This motivational factor placed value on the preservation and care for collections over time. This factor was mentioned in Mi and Pollock [16], Debruyne et al. [47], Coppens et al. [35], and Hyvönen et al. [32].

**3.3.7 Research Needs.** This was by far the most frequently cited reason for undertaking a linked data project, seen in 23 of these studies. These projects are motivated by the desire to publish data to fulfil a specific research need [29, 36, 41, 46], to make specific collections more accessible for research [17, 48, 49, 50] or to create tools to improve the experience of researchers [38].

**3.3.8 User Needs.** This theme is closely related to both Research and Education, but covers the remaining motivating factors derived from specific needs. In some cases, these needs were taken from user needs analysis [22, 26] and some were directed towards improving user experience more generally [32].

The frequency of these eight categories can be seen in Figure 5. The distribution of these categories among the studies considered in this review can be seen in Table 2. Most studies showed more than one motivating factor, and therefore the data displayed is based on instances of each theme rather than the single motivation of each study. Research was the most frequently cited reason for these projects, and was mentioned in 23 studies overall, or 54.8% of the studies included. Exploration of the area of linked data also occurred frequently, appearing in 15 studies, 35.7% of those surveyed. User needs were mentioned in 11, or 26.2% and discoverability was a factor in 8 or 19%. Education and interoperability were both considered in 5 studies or 11.9%, and the needs of GLAM organisations and preservation were mentioned in 4, or 9.5% of studies, respectively. Overall, it appears that research needs, exploration of linked data itself, user needs, and discoverability were the most common factors motivating these projects.

Table 2. Distribution of Motivational Factors between Studies Under review

Publication	Exploration of linked data	Discoverability	Education	GLAM needs	Interoperability	Preservation	Research Needs	User Needs
Mi & Pollock (2018) [16]		x				x	x	
Adamou et al. (2018) [41]			x				x	
Valentino (2017) [17]	x	x			x		x	
Cole et al. (2017) [18]							x	
Mäkelä et al. (2017) [48]							x	
Velios & Martin (2017) [49]							x	
Binding & Tudhope (2016) [46]					x		x	
Debruyne et al. (2016) [47]						x	x	
Tharani (2015) [52]	x						x	
Ryan et al. (2015) [29]	x		x				x	
Southwick (2015) [19]	x		x					
O'Dell (2015) [42]			x				x	
Vila-Suero & Gomez-Perez (2013) [21]				x				
Pattueli (2012) [53]	x						x	
Clough et al. (2011) [22]								x
Hypén & Mäkelä (2011) [23]				x				x
Daquino et al. (2017) [37]	x							
Niang et al. (2017) [43]					x			
Martin & Guenther (2012) [38]							x	
Mathews & Smart (2016) [50]							x	
Chardonens et al. (2018) [26]								x
Peroni, Tomasi & Vitali (2013) [31]							x	x
Tallerås et al. (2014) [44]					x		x	
Van Hooland et al. (2015) [59]	x						x	
Tibaut, Perhavec & Kaucic (2017) [54]							x	
Colace et al. (2015) [55]							x	
Jordanous (2015) [20]	x						x	
Ronfard et al. (2015) [34]	x		x					
Vassallo et al. (2013) [56]		x						
Ahonen & Hyvonen (2009) [24]							x	
Bojars (2016) [25]							x	x
Dannélls et al. (2012) [30]		x						
De Boer et al. (2012) [45]	x				x			
Nguyen et al. (2015) [57]								x
Dijkshoorn et al. (2014) [58]								x
Achichi et al. (2015) [27]	x	x						x
Coppens, Mannens & Duersen (2011) [35]		x				x		x
Hyvönen et al. (2009) [32]				x		x		x
Winer (2014) [28]	x				x		x	x
Farrokhnia & Zarei (2013) [33]	x	x						
Skevakis et al. (2014) [39]	x	x						
Van Hooland et al. (2013) [40]	x							

#### 4 DISCUSSION

This systematic review has revealed that there is a significant lack of diversity in terms of the organisation types involved with linked data projects in cultural heritage. The motivations behind its adoption are closely tied to the organisations most frequently involved in these projects, and there is a lack of representation for smaller, perhaps more risk-averse, organisations such as public libraries, museums, and galleries.

The frequent inclusion of universities in the projects studied here is not surprising given the fact that linked data is still relatively new to the cultural heritage sector. As universities focus on research and innovation, it is unsurprising that they would be early adopters of these technologies. Participants in university-led projects are perhaps also more likely to publish research papers relating to their projects, which may also explain the high level of university representation. It is also unsurprising that National Libraries and Archives were frequently involved, as these organisations are likely to take a leading role in cultural heritage innovation in a given country.

An unfortunate reality revealed by this study is the lack of representation for public libraries and museums in this area. As can be seen in the Kirjasampo project described by Hypén and Mäkelä [23] which developed a system for recommending fiction to public library patrons, there are innovative uses to be made of linked data in public libraries. This is emphasised even further by the relatively low instance of user needs as a motivating factor compared to research needs.

The high proportion of collaborative projects within this study could be said to be expected, based on the rhetoric surrounding linked data. For this reason, however, the fact that there are eight projects which did not appear to involve collaboration with external parties is surprising. The studies included in this review span the whole spectrum of collaboration, from consortiums of over thirty institutions [28, 32], to those containing no evidence of external collaboration whatsoever [22, 25, 49]. This suggests that, although the collaborative benefits of linked data are seen as a core benefit of these technologies, these projects do not necessarily take a collaborative approach. There is, of course, a limitation to this analysis, in that it is largely based on the reporting of collaborative partners in these articles, and some supplemental research. These non-collaborative studies may have involved unnamed external parties.

The fact that the motivating factor of interoperability occurred relatively infrequently is also surprising, as related benefits such as uniformity and standard practices were identified as a motivation behind publishing cultural heritage linked data by Feitosa et al. [11], and the issue of siloed metadata has been identified as an issue in the cultural heritage sector more broadly [5]. The lack of emphasis placed on this benefit by the authors of these case studies could, however, be due to the fact that interoperability of metadata is one of the more obvious benefits of linked data, and the authors therefore did not feel it necessary to explicitly state this as a motivating factor. The presence of the eight projects which did not show collaboration, and the lack of emphasis on interoperability are surprising, and suggest that the ideals of sharing data and working collaboratively which are often cited as the key benefits of linked data are not necessarily the benefits which appeal most to cultural heritage professionals. The greater emphasis on improving discoverability and usability of collections suggests that there is greater interest in promoting collections from the authors' own institutions rather than sharing data or combining collections for wider use.

As regards the motivating factors cited in this study, the prevalence of research as a factor is unsurprising given the high level of university involvement in these projects. The theme of education is also mentioned in several of these works and is closely related to research needs in that it responds to a specific user need, and also in that it most likely results from the high proportion of universities which are represented.

The frequent mention of contributing to or exploring linked data as motivation for these projects is interesting. It suggests that many projects are exploratory in nature and are intended to explore the applications of linked data. It also indicates that there is enthusiasm for this technology, and an awareness of its growing adoption, or at least of the hype surrounding it. This enthusiasm on the part of universities and national organisations may be beneficial in that it may result in guidelines which may help smaller organisations in future.

The proportion of these exploratory projects suggests that linked data is taken seriously by the cultural heritage sector as a potentially useful technology, though it may still be in the early stages of adoption. This suggests that perhaps linked data is moving out of the Gartner 'trough of disillusionment' [4] into the 'slope of enlightenment' which may lead to that coveted place of productivity. Rather than suggesting that the cultural heritage sector has been left behind in the rise of linked data, as Van Hooland and Verborgh warn their readers [51],

this may suggest that the cultural heritage sector is keeping pace with the emergence of linked data, or at least certain organisation types are. Many of the studies that cited contribution to linked data as a motivating factor expressed a desire to create guidelines, or at least produce an example, for others [17, 19, 20, 37, 39], and this work will ideally pave the way for other organisations to implement similar projects. However, this intention does not guarantee that this vision of a trickle-down system of technological progress will become a reality, and attention may need to be paid to ensuring that barriers to participation in linked data technologies are lowered over time.

## 5 RECOMMENDATIONS

The primary concern raised in this study is that there remains work to be done in democratising the use of linked data. The projects considered here were disproportionality conducted, either partially or in full, by universities and national institutions. Further study is needed to assess what barriers are in place which prevent public libraries, smaller museums, galleries, and other under-represented organisations from either undertaking these projects or from publishing case studies of their projects.

As the wider project of linked data and the creation of a semantic web is dependent on wide adoption of linked data, these barriers should be removed to allow for wider participation. In order to do this, further analysis of these barriers will be required to identify the main obstacles to linked data adoption and offer solutions to overcome these obstacles. A survey of cultural heritage organisations would be useful to determine what obstacles are preventing them from engaging with linked data. Possible barriers may include limited financial and human resourcing, unmet training requirements, or a lack of adequate technical infrastructure. The collection of detailed data to describe these barriers would provide a basis from which to design informed solutions to these problems.

Analysis of the training offered to cultural heritage professionals would also be useful to determine whether there are any educational gaps which may be preventing organisations from engaging with linked data. Course curricula in a wide range of educational fields which are common in the cultural heritage sector (e.g., library studies, information science, archival studies, museum studies, cultural policy, etc.) could be considered, and the degree to which they include an adequate introduction to linked data ascertained.

The high proportion of university projects included in this review may also be due to the fact that university staff may be more likely to publish their findings in a peer-reviewed format than those working in other cultural heritage settings. Academic librarians and archivists are often encouraged or obliged to produce scholarly publications [60], whereas this is not a common requirement for their counterparts in public libraries or other cultural heritage organisations. Further research into the information-sharing behaviour of cultural heritage professionals would be useful in order to determine whether certain organisation types are being excluded from discussion around technologies like linked data, and whether better methods of information exchange exist or could be developed.

Ensuring adequate resourcing of smaller cultural heritage organisations, and ensuring that cultural heritage professionals are equipped with the requisite skills to engage with linked data, will ensure that this technology can be used to its full potential in the cultural heritage sector.

## 6 CONCLUSION

This article provides an in-depth study of the implementation of linked data in the cultural heritage sector through a systematic literature review of case studies of implemented linked data projects in this sector. This literature review indicates that linked data in cultural heritage is in an early stage of adoption and considerable effort is needed before this technology is of benefit to every area of the sector. The study suggests that there is great interest in exploring the uses of this technology, and that adoption does not appear to be falling significantly behind the overall trend.

There is further indication that the ideals espoused by Berners-Lee and others are echoed in this cultural heritage literature: collaboration plays a key role in most of these studies, and the motivating factors of research needs, education, discoverability and interoperability align with the desire to “open up the knowledge and workings of humankind”. [1]. This suggests that the ideals of the linked data movement are central to many of these projects and that the overarching vision behind the semantic web has been internalised by the sector. However, this review shows that the motivating factors behind these projects are varied and do not necessarily align with the most frequently noted ideals of the semantic web. Cultural heritage professionals may focus on the benefits of linked data in promoting their collections by making them more discoverable, rather than focussing entirely on these ideals of sharing and collaboration.

Although the concepts of linked data and semantic technologies have been around for some time, its adoption is still at an early stage, and sufficient maturity of these technologies for widespread application and adoption in sectors such as cultural heritage and GLAM is questionable. There remains work to be done in assessing the needs of the cultural heritage sector in relation to these concepts, the success of projects already implemented, and potentially significant further work to be done to rectify any gaps which prevent the sector from using the technology to its full potential.

## A APPENDIX

### A.1 Breakdown of Studies and Their Studied factors with Respect to Research Questions

In text reference	Name of Project	Type of org involved	Collaboration	Motivations
Mi & Pollock (2018) [16]	3D digital models of cultural heritage collections at the University of South Florida	University Lib	Yes, not stated	Research needs, Discoverability, Preservation
Adamou et al. (2018) [41]	The Listening Experience Database	Multiple universities	Yes	Research needs, Education
Valentino (2017) [17]	Oregon State University Historical and Cultural Textile and Apparel Collection	University library	No	Research needs, Exploration of LD, Interoperability, Discoverability
Cole et al. (2017) [18]	2 Emblem Books projects	University library, Library	Yes	Research needs
Mäkelä et al. (2017) [48]	WWI LOD: World War I Linked Open Data	University library	Yes	Research needs
Velios & Martin (2017) [49]	Ligatus Centre Decorated Papers Database	University, Research centre	No	Research needs
Binding & Tudhope (2016) [46]	ARIADNE	Government bodies, Research repository (ADS)	Yes	Research needs, Interoperability
Debruyne et al. (2016) [47]	Irish Record Linkage	Repository, Universities	Yes	Research needs, Preservation
Tharani (2015) [52]	Converting Harvard Ginans Collection to BIBFRAME	University library, University	No	Exploration of LD, Research needs
Ryan et al. (2015) [29]	Linked Logainm	Government, University, Repository, National library	Yes	Exploration of LD, Research needs, Education

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In text reference	Name of Project	Type of org involved	Collaboration	Motivations
Southwick (2015) [19]	UNLV LOD	University library	No	Exploration of LD, Education
O'Dell (2015) [42]	ARLIS/NA Artist's Book Thesaurus	Library society	Yes	Education, Research needs
Vila-Suero & Gomez-Perez (2013) [21]	Datos.bne.es and MARiMBA	Government, National library, University	Yes	Library needs
Pattuelli (2012) [53]	Linked Jazz	University	Yes, not stated	Exploration of LD, Research needs
Clough et al. (2011) [22]	Linking Geographic Placename data at the National Archives	National archives	No	User needs
Hypén & Mäkelä (2011) [23]	Kirjsampo	Public library, University, Research, Foreign public library, National library, Private company	Yes	User needs, Library needs
Daquino et al. (2017) [37]	Zeri Photo Archive LD	Art foundation, Consortium	Yes	Exploration of LD
Niang et al. (2017) [43]	PARCOURS Project	Governments	No	Interoperability
Martin & Guenther (2012) [38]	WissKI	Research universities, Research foundation	Yes, not stated	Research needs
Mathews & Smart (2016) [50]	Piloting Linked Open Data on Artists' Books (PLODAB)	University library	Yes, not stated	Research needs
Chardonnens et al. (2018) [26]	Mining user queries with information extraction methods and linked data	University library, National library	Yes, not stated	User needs
Peroni, Tomasi & Vitali (2013) [31]	Europeana	Europeana	Yes	User needs, Research needs
Talleràs et al. (2014) [44]	TORCH Project	University	Yes	Interoperability, Research needs
Van Hooland et al. (2015) [59]	Exploring entity recognition and disambiguation for cultural heritage collections	Museum, Universities	Yes, not stated	Research needs, Exploration of LD
Tibaut, Perhavec & Kaucic (2017) [54]	Knowledge modelling of buildings	University	No	Research needs
Colace et al. (2015) [55]	Campagna: Cultural Heritage	University	No	Research needs
Jordanous (2015) [20]	The Sharing of Ancient Wisdoms Dynamic Library and the DEFRA DTC Archive.	Universities	Yes, not stated	Research needs, Exploration of LD
Ronfard et al. (2015) [34]	Capturing and Indexing Rehearsals	Universities, Private company	Yes, not stated	Exploration of LD, Education
Vassallo et al. (2013) [56]	Byzantine Museum and Art Gallery of the Archbishop Makarios III foundation LD	Research centre	Yes, not stated	Discoverability

(Continued)

## Continued

In text reference	Name of Project	Type of org involved	Collaboration	Motivations
Ahonen & Hyvonen (2009) [24]	Part of the National Semantic Web 2.0 (FinnONTO 2.0)	National library, Government, University	Yes	Research needs
Bojars (2016) [25]	LD at the National Library of Latvia	National library	No	User needs, Research needs
Dannéls et al. (2012) [30]	Multilingual Online Translation (MOLTO)	EU	Yes, not stated	Discoverability
De Boer et al. (2012) [45]	Supporting linked data production for cultural heritage institutes at the Amsterdam museum	Museum	Yes, not stated	Exploration of LD, Interoperability
Nguyen et al. (2015) [57]	CURIOS Mobile	University	Yes	User needs
Dijkshoorn et al. (2014) [58]	Using Linked Data to Diversify Search Results	University, Museum	Yes	User needs
Achichi et al. (2015) [27]	DOREMUS	National library, University, Private companies, Public bodies	Yes	Discoverability, Exploration of LD, User needs
Coppens, Mannens & Duersen (2011) [35]	Publishing Provenance Information on the Web using the Memento Datetime Content Negotiation	University library, University, Private company	Yes	Preservation, Discoverability, User needs
Hyvönen et al. (2009) [32]	CultureSampo	Government, university, Private companies, Public organisations	Yes	Library needs, Preservation, User needs
Winer (2014) [28]	Judaica Europeana	Society, University library, National library	Yes	Interoperability, User needs, Research needs, Exploration of LD

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