

Article

The Landscapes of Sustainability in Library and Information Science: Diachronous Citation Perspective

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Abstract: Sustainability issues constitute a distinct subdiscipline of librarianship and information science, with its own areas of study, methods, and areas of application. Despite being nearly 30 years old, there are still divergent opinions on its current phase of development and its links to other scientific disciplines. The authors aim to clarify and summarize the ongoing discussion through citation analysis, shedding light on the lifecycle of research papers in sustainability-oriented library and information science, the current research subjects of focus, the influence of subdomains within the discipline on other scientific areas, and the overall quantitative and qualitative landscape of the discipline. A detailed elucidation of the inquiry's results is intended to outline the discipline's cognitive structure and its impact on sustainability science. The lifecycle of disciplinary papers indicates the dynamic development of the field. Sustainability-oriented library and information science is well-established, and its research focus has already been consolidated. The optimal citation window for measuring the impact strength in this discipline is a period of 3 to 4 years. "Culture" and "Education" have been identified as the most forward-looking subdisciplines, whereas "Buildings" and "Collections" exhibit less dynamic growth. The social sustainability pillar is the dominant one, while the environmental pillar is slightly less prominent. The economic pillar is the least represented. Although the majority of information exchange occurs within the discipline, it maintains strong and numerous links with several other fields, including both technical and social sciences, as well as the humanities.

Keywords: library and information science; sustainability; diachronous citation analysis; trend analysis; network analysis



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1. Introduction

The issues of sustainable development and the phenomenon of sustainability itself have already found their place in many different scientific disciplines, and library and information science (LIS) is no exception here. The possibly very first paper related to the issues in question, which appeared in the field of LIS, was published in 1995 by Amanda Spink [1], and the next one emerged in 1997 and was authored by a pair of Russian librarians: Boris Elepov and Olga Lavrik [2]. As time passed, the number of publications inspired by the sustainability movement was rapidly growing, which eventually resulted in the molding of a new independent research perspective in the traditionally understood librarianship and information science. The expansiveness of this strand of research is manifested, among other things, through an increasing number of review articles being published on a regular basis (see, e.g., [3–10]).

The study of sustainability-related phenomena by members of the LIS community typically focuses on several recurring areas of interest, which include the following: (i) sustainable architectural and spatial planning of library buildings; (ii) sustainable information

and communication technologies (ICTs); (iii) sustainable financing, acquisition, and weeding of library collections; (iv) the role of education in raising awareness of sustainability issues and promoting sustainable citizenship; (v) the cultural dimension of sustainable development; and (vi) other aspects of sustainability science that are vital for libraries, librarians, library services, and their daily practices.

Even considering the numerous global trends constantly emerging in sustainability science, it can be stated that LIS has identified its own original research problems, through which it contributes to the ongoing international debate on achieving the United Nations Sustainable Development Goals (SDGs) [11]. The SDGs, as a set of individual goals, can be roughly divided into three basic categories (the “three pillars” or the “triple bottom line”): environmental, economic, and social. A fourth pillar, the cultural dimension of sustainability, is also increasingly mentioned in the literature, a rarity before 2001 [12].

LIS is thus capable of defining its identity, in the context of the ongoing, world-wide efforts aimed at “The future we want” [13]. This capability of the sustainable LIS field has also been observed and exemplified during the 2021 IFLA World Library and Information Congress [14].

Bibliometric analyses are usually conducted on the basis of scholarly journals, which serve as a communication platform for the scientific community. Scientific journals not only facilitate and support but also accelerate the process of creating new knowledge. This function makes journal articles a suitable unit for bibliometric and scientometric analyses.

The authors of the present article turned to bibliometric methodology with the aim of answering the following research questions:

- Q1: What does the lifecycle of a publication in the sustainable LIS specialty look like when viewed from the perspective of a diachronous citation analysis?
- Q2: Which research topics are currently gaining popularity, and which are fading away in the landscape of sustainable LIS science?
- Q3: Which subdomains of sustainable LIS are cited by which other scientific disciplines the most, i.e., what are the properties of the diachronous citation network in terms of the distribution of the direct citation links connecting some particular fields of study?
- Q4: What is the overall quantitative and qualitative picture of the current state of the sustainable LIS specialty, based on bibliometric methods of analysis?

Some of the above-stated questions have already been preliminarily investigated by the authors of this article (see [6,7]). However, a different method of analysis was used in those studies. Specifically, instead of citations, two other quantitative metrics were employed: (i) the number of scientific papers published in a given discipline within a given time period, and (ii) the number, size, and structure of collaborative efforts undertaken by members of the sustainable LIS scientific community.

Citation analysis is likely to be the next logical step in uncovering the holistic structure of the specialty under study, its pattern of temporal evolution, and its role in international scientific communication. The previously selected units of analysis now serve to supplement and enrich the findings of this article. Additionally, they aim to provide deeper insight into the multilayered cognitive structure of the field under examination.

This paper is organized as follows: Section 2 provides the background for the research, including an introduction to previous bibliometric analyses of sustainability literature and the identification of a research gap in the field of LIS. Section 3 explains the methods used for the bibliometric analyses, while Section 4 presents the findings. Section 5 discusses the study’s limitations, and Section 6 interprets the results and proposes further directions for research. The final section is the conclusion.

2. Background

Due to the fact that sustainability research is a dynamic and rapidly expanding field of science, it seems natural that many bibliometric and scientometric analyses of its structure and various quantitatively measurable features have emerged.

Among the most noticeable examples of such analyses, we can enumerate a very broad view of the whole sustainability field, which was presented by Bettencourt and Kaur [15]. The authors collected data on the thematic structure of the analyzed domain, its path and pace of evolution in time, and the collaboration structure. Quental and Lourenço [16] identified the most prominent authors, references, and journals that influence and underpin the sustainable development literature. They also identified major research areas that contribute to sustainability science. Interestingly, one of them was termed “the development and sociology of science” and, due to its clear connection to science of science, it can presumably be associated with the broadly understood LIS domain ([16], p. 375).

Schoolman et al. [17] investigated the extent to which sustainability science lives up to the conception of an interdisciplinary domain. The authors’ results show that sustainability is in fact more interdisciplinary than other fields, but does not meet the expectations inherent in the triple bottom line model. The economic pillar is the most heterogeneous, while the environmental pillar draws the least from outside research areas ([17], pp. 69, 78).

Buter and Van Raan [18] investigated the same three interdisciplinary ‘pillars’ of knowledge on which sustainability science is founded. Their main finding is that the primary focus in the sustainability literature is mostly on economics and ecology, and the social sciences perspective is less frequently present in scholars’ perspective ([18], p. 265).

Wichaisri and Sopadang [19] turned to a co-citation method to distinguish leading thematic clusters of articles and to display the trends, and composition of the current state of research in the sustainable development domain. Future prospects of the field in question were determined through the means of temporal analysis, i.e., by looking at the process of shaping the most common issues that are dominant in different periods.

Farrukh et al. [20] focused on the content of the journal “Sustainable Development” as a representation of the transformations and progress that were taking place in the field under study in the 27-year time span (1993–2019). Well-known bibliometric methods of co-citation, bibliographic coupling, and articles’ keywords co-occurrence were applied, which resulted in a detailed description of the journal’s publication patterns, its prospective and retrospective citation trends, as well as in the identification of research gaps.

Sianes et al. [21] conducted a comprehensive bibliometric analysis of the worldwide academic production on the SDGs, which was published between 2015 and 2020. The authors argue that a better understanding of this body of research is needed if we want to further strengthen evidence-based policies essential to support the real-life implementation of the assumptions of the 2030 Agenda for Sustainable Development.

Nevertheless, in the vast subject literature, it is also possible to find examples of strictly bibliometric analyses, which are performed not so much on sustainable science literature, but which take a much narrower focus, i.e., precisely, a set of sustainable LIS publications. The authors, however, who conduct their research on the basis of such publications, have a somewhat different purpose in mind. For example, a citation analysis may have been performed with the aim of compiling a comprehensive review of the literature, which precedes the author’s own research.

One of the works that falls into this category is Meschede and Henkel’s [10] review article, which aimed to analyze the content and methodological approaches prevalent in most of the research published within the sustainable LIS domain. In 2018, Meschede and Henkel published another article that also employed bibliometric methods [22]. Their work focused on identifying opportunities for LIS to contribute to the sustainability and sustainable development debate. The authors also detailed eight major topics most frequently addressed by members of the LIS community ([22], p. 872).

A different motivation for using bibliometric methods can be found in the paper by Goodchild and Zhao [23], where the authors present a way to assess a library collection composed of sustainability-related items. The evaluation focused on users’ citation behavior, the completeness of the collection, and identifying top-priority journals that should always be included in the library’s subscriptions. The latter was investigated using Bradford’s law of scattering ([23], p. 156).

Repanovici et al. [24] conducted a scientometric study of the sustainable LIS literature to identify the most prominent keyword clusters and, subsequently, to reveal the main research directions. In other words, the authors identified the scientific frontier of the discipline, as well as the concepts that are currently dominant.

Beutelspacher and Meschede [25] examined the role of public libraries in promoting environmental sustainability ideas and used a bibliometric method of algorithmic clustering to visualize a network of keywords that appeared in nearly 1400 books held by libraries at the time of their study. They employed the VOSviewer tool, a computer program for bibliometric mapping of selected parameters or properties of the literature corpora (see e.g., [26]).

Academic libraries and the sustainable aspects of their management have recently been the subject of another bibliometric analysis conducted by Ensslin et al. [27]. The authors examined several quantifiable parameters of the literature sample chosen for the study and identified, among others, the most prominent journals, articles, and authors, the countries with the strongest citation links, as well as the most frequently used keywords, which offer insights into the vision of sustainability that scholars are working on ([27], pp. 1693–1697). Based on the quantitative characteristics of this research area, the authors made key recommendations for libraries and their “parent institutions”, operating in the higher education sector. Particularly significant is the authors’ call for alignment with the trend toward integrating sustainability issues with organizational values and strategic objectives to build a more comprehensive model for sustainable library management in higher education institutions ([27], pp. 1705–1706).

Two more studies, that are somewhat related to the present one, were published a short time ago by Fedorowicz-Kruszewska [28] and by Li and Yang [29]. Both of them utilized a range of bibliometric methods and both took under scrutiny the concept of “green libraries”. The first mentioned paper aimed to determine the numerical increase in publications on green libraries over a 30-year time period (1991–2020) and to identify the thematic structure of the field. Fedorowicz-Kruszewska combined annual growth rate of publications’ number with content analysis and found that systematic increase in publishing activity only began in 2007. The largest increase in publications occurred in 2013 and 2018 and, according to the author, resulted from the publication of two collective works on green libraries under the auspices of the IFLA ([28], p. 916). The leading subject categories that describe the content of the analyzed body of literature were “Building and its management”, “Programmes, services, projects”, “Cooperation with the external environment”, and “Collection” ([28], pp. 923–924). The core inference of the work is the need of developing a codebook that could be used to evaluate libraries’ activities in respect of adherence to the ideas of sustainable development.

Li and Yang [29] adopted a broader set of bibliometric tools to assess current trends in publication patterns, including the research fields to which articles belong, the most cited authors and journals, and the spatial distribution of their affiliations. Based on the analyzed set of publications, the authors made the same observation as noted by Fedorowicz-Kruszewska [28]: before 2007, research on green libraries was in its early stages. The knowledge base in the field, i.e., the most significant research topics, was examined using co-citation and keyword clustering methods. The most influential works focused on information technology and its relationship with the environmental sustainability of libraries, as well as various measures to “green” library buildings and their services. Digital library construction, digital preservation, library education, and libraries’ social responsibility were also considered important. The analysis of journal contributions revealed that various disciplines—such as electronic engineering, library and information science, and construction and building technology—have their own specific research priorities. Overall, there is notable multidisciplinary integration that enriches the scientific approach to the green library concept. As for leading countries, the USA and China are at the forefront of new developments in this area of study. However, the overall number of publications remains small, with reports of a lack of in-depth research and the low citation impact of the

collective scientific output ([29], p. 18). Nonetheless, regarding trends, there is increasing focus on the sustainable library field, which, the authors hope, will eventually demonstrate its value and enhance the global sustainable development research agenda.

In summary, it appears that the bibliometrically oriented research is fairly frequently conducted in cases where the empirical base for the scholars is the general sustainability literature, i.e., publications that stem from unexpectedly diverse range of scientific specialties, as studies have shown. The main contributors are undoubtedly environmental scientists, economists, and certain social scientists. The fourth pillar of sustainable development, i.e., culture, is relatively new and still not fully explored area, which presents opportunities for further research.

However, when the empirical base for quantitative analysis is limited to sustainability issues in the field of library and information science, such analyses are considerably rarer. Consequently, it can be ascertained that the sustainability research landscape in LIS is still only partially explored and may conceal many phenomena that are worth discovering. This observation was the main motivation for the authors of this paper to extend their previous research by adopting a diachronous approach.

3. Materials and Methods

3.1. Data Sources

Two datasets were used to conduct the present diachronous study. Both were extracted from the Scopus–Elsevier database, which is regarded as one of the most comprehensive bibliographic data sources and is recognized for including more high-quality, peer-reviewed publications than other databases [30]. The first dataset was formed during a systematic literature review [6] conducted as a preliminary stage of the broader research project undertaken by the authors, of which this paper is also a part. In that review, the main research directions (i.e., topical areas) of sustainable LIS were identified, providing the research context for this article, along with the rationale for the search query used and a description of the data-cleaning process involved.

At this stage, the Scopus–Elsevier platform was selected, as it is widely regarded as one of the most comprehensive and exhaustive bibliographic data sources available. It is recognized for its inclusion of a greater number of high-quality, peer-reviewed publications compared to other databases. Utilizing the interface provided by the Scopus website, the following search query was formulated to facilitate the retrieval of bibliographic records:

```
( TITLE-ABS-KEY ( sustainab* )
  AND ( TITLE ( library OR librari*
              OR "information scienc*" ) )
)
AND ( LIMIT-TO ( DOCTYPE , "ar" )
      OR LIMIT-TO ( DOCTYPE , "cp" ) OR LIMIT-TO ( DOCTYPE , "ch" )
      OR LIMIT-TO ( DOCTYPE , "bk" )
    )
```

3.2. Data Acquisition, Cleaning and Preprocessing

A year after completing the research for the authors' first article (on 2 January 2023), bibliographic records citing each scientific work in the first dataset were retrieved from the Scopus platform (if any citations existed for a given work). Thus, the second dataset was formed.

It is worth noting that both of these datasets may have (and in fact do have) some conceptually common part represented by records from each of these sets individually, but representing the same scientific works. This relationship is shown in Figure 1.

Regarding the diffusion of sustainable LIS ideas across other scientific disciplines, it is worth noting that quantitatively or factually assessing the influence and diffusion based on scientific literature would require assigning each citing scholarly work to a specific field of study, while valuable initiatives such as DOI and ORCID are advancing academic

publishing, there is currently no standardized method for assigning research papers to distinct disciplines. That is why the authors chose to employ the All Science Journal Classification (ASJC) codes provided by Scopus, an established classification system that remains the most suitable approach, in the authors' opinion. The practice of using ASJC codes and their usefulness in the field of bibliometrics is also confirmed by the fact that they are currently of interest to researchers publishing in a journal focused on the development of bibliometric methods [31]. The ASJC codes were assigned to each record representing a scientific work from the second dataset, based on the source (journal) in which the work was published. Additionally, keywords and a country—determined by the affiliation of the corresponding author—were assigned to each record. The data prepared in this manner provided a robust foundation for various diachronous citation analyses across different cross-sections.

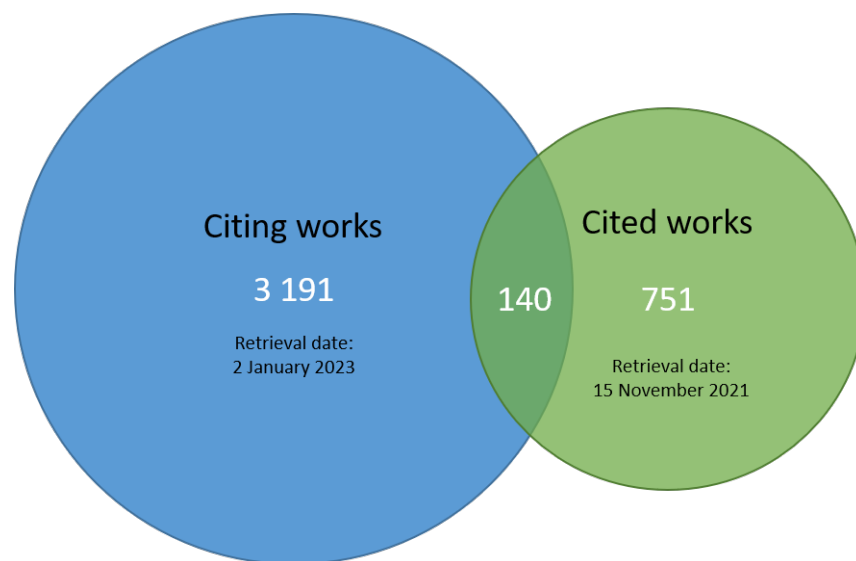


Figure 1. Datasets used in the study.

3.3. Diachronous and Network Analysis

Diachronous citation analysis was chosen with the intention of analyzing the lifecycle of papers within the sustainability-oriented LIS discipline, and their influence on other scientific domains. The relationship between citation-based metrics and sustainability issues examined in LIS is assumed to be a dependence analogous to the one that exists between the object and method of study. In other words, sustainability-related topics that are addressed in LIS represent the object of study, and were extracted by means of the literature content analysis, whereas tracking citations that this body of the literature received is a method of identification of the nature of resonance that these publications have generated in the LIS community. This approach is in accordance with the generally accepted view of the classical citation analysis' purpose and capabilities. Its strength lies not in the ability to strictly define and distinguish some particular set of papers dealing with a certain topic, but rather in the possibility of drawing conclusions about quantitative and also, concededly indirectly, qualitative properties of a scientific domain. Additionally, the definition, shape, and composition of such domain were revealed through detailed linguistic scrutiny of the semantic content of documents indexed in a reputable digital database.

Regarding the diachronic analyses, two approaches were used. In the first, the timeline shows the number of citations that appeared in a given year, broken down by the specified topical areas of the cited works. This is intended to illustrate the specifics of changing interest in scientific publications over time within each topical area. The second approach utilizes the method proposed by Finardi [32], which abstracts from absolute time values. Instead, non-negative integers representing the age of a given publication (expressed in

years) are placed on the abscissa axis, while the ordinate axis displays the sum of citations for all publications of that age. This analytical perspective also considers the topical areas of cited scientific works, providing an overview of the specifics of the lifecycles of the analyzed literature within these areas. The topical areas discussed in this paper have been adopted from the authors' previous study [6] and are as follows:

- Information and ICT;
- Collections;
- Buildings;
- Education;
- Culture;
- Other.

Tagging each citing work with the ASJC code and country enabled analyses illustrating the degree of diffusion of the sustainable development ideas promoted by LIS into various branches of science and countries. A derivative of the diachronic perspective is the method of co-citation analysis [33,34], which identifies semantic similarity or complementarity among works that are simultaneously cited by other publications. For this reason, it was decided to conduct such an analysis in this research as well.

In addition, to validate the hypothesis regarding the more frequent citation of multi-author papers in the LIS field, analyses were conducted that took into accounting for the number of authors of each scientific paper.

4. Results

The two datasets described in Section 3 served as the sole basis for the analyses, the results of which are presented below.

Starting with Finardi's approach, the citations of the entire corpus of the relevant literature were analyzed first, as illustrated in Figure 2. It can be observed that the highest "bloom" of scholarly work, as measured by the number of citations in each year of its presence in the scientific community, occurs in the 2nd and 3rd years of its life. Additionally, works are cited quite frequently in the 1st, 4th, and 5th years, after which, interest in them gradually declines in a manner resembling an exponential distribution.

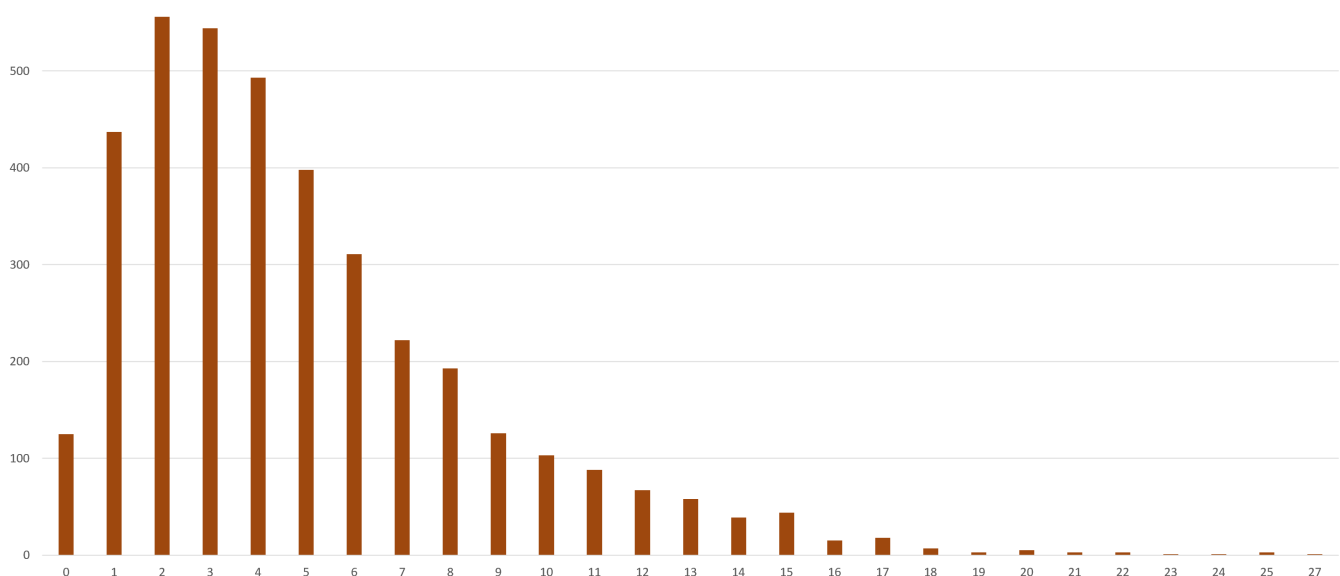


Figure 2. Citation count of scientific works in LIS throughout years of their lifespan.

Breaking down the histogram into individual topical areas yields Figure 3. It is evident that the greatest interest (measured by the number of citations) is in the areas of Information and ICT and Others, with medium interest in Education, and the least interest

in the remaining areas. This gradation aligns with the quantitative shares of papers in each topical area within the corpus of cited papers ([6], Figure 2), indicating that no significantly higher interest (as measured by citations) was observed in any particular topical area.

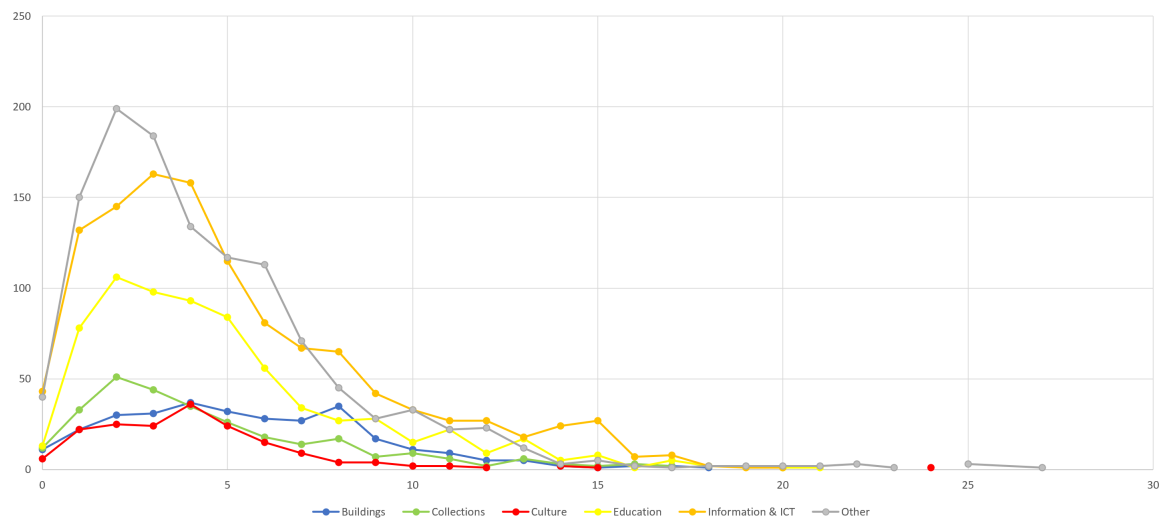


Figure 3. Citation count of scientific works in LIS throughout years of their lifespan by topical areas.

A more insightful perspective on the lifecycles of scientific publications was gained by normalizing the data against the number of citations in each subject area, ensuring that the total number of citations within each area across all years of their lifecycle summed to 100%. This is illustrated in Figure 4. It shows that the shortest lifecycles are characterized by the subject areas of Collections and Others, which reach their peak at the age of two years, after which interest in them gradually declines. In contrast, the line representing topics related to Buildings appears the flattest, indicating a notably extended lifecycle. Notably, the red line (representing Culture topics) does not reach its maximum until the fourth year, after which it drops sharply, eventually falling below all other topics by the seventh year.

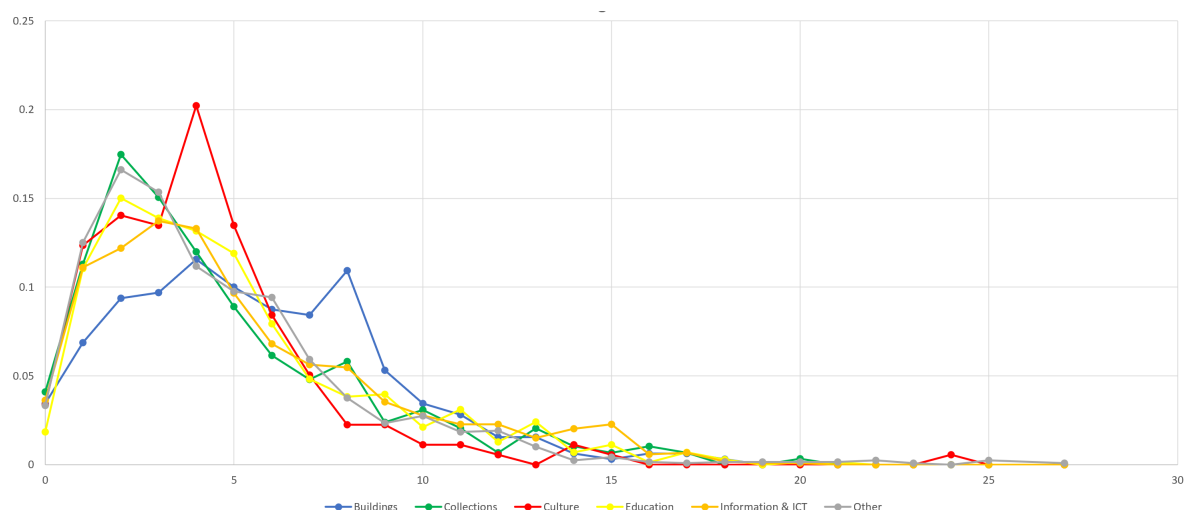


Figure 4. Normalized citation count of scientific works in LIS throughout years of their lifespan by topical areas.

Figure 5 shows coefficients of the cumulative number of publications and their citations by category over the years. The individual values in the chart, calculated for each topical area separately, for a given year are the quotient of the cumulative number of citations from the beginning to the given year and the cumulative number of scientific papers from the beginning

to the given year. To further illustrate the content of this chart with a concrete example, let us focus on the blue line (representing the Buildings topical area) and the value of 2, which it reaches in 2018. This means that, in 2018, each work (regardless of its publication date) from the Buildings area has been cited an average of 2 times. The sharp spike in the red line (representing a topical area of Culture) is clearly visible from 2008, reaching its peak in 2011. A similar trend, though less pronounced, is observed in the Education area. Notably, after temporary declines in both Culture and Education, a renewed increase is observed in 2022.

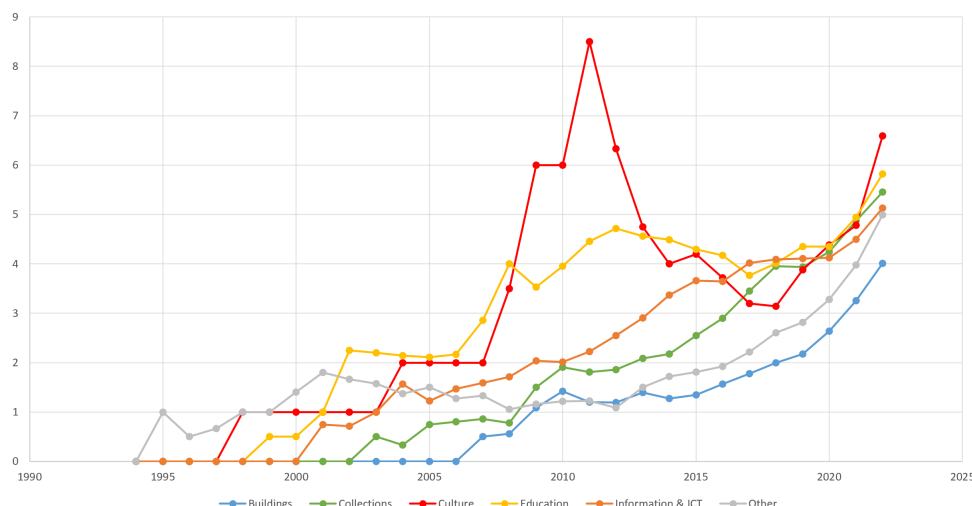


Figure 5. Quotients of the cumulative number of publications and their citations by category over the years.

Given a collection of cited scientific papers and a corresponding set of papers that cite them, it is worthwhile examining the phenomenon of co-citation.

Co-citation analysis is regarded as a method to gain insights into the cognitive structure of a specific scientific field by identifying key publications (authors, journals, and keywords). This method was first proposed in 1973 [33,34] and its basic premise is that the simultaneous citation of two different documents by a third, later-published document, establishes a content link between the first two documents. The more frequently a pair of papers is co-cited by subsequent publications, the stronger the link between them. Since then, i.e., since the mid-1970s, the method of co-citation analysis has been repeatedly used to identify leading research trends or to identify major developments in specific disciplines. Numerous variations of the method have been developed to increase its precision and the relevance of the results (see, e.g., [35–42]).

To build a co-citation network, fractional counting was used, since it is believed to offer a more informative perspective than full counting [43]. The central part of the co-citation network is shown in Figure 6. A pair of articles from a set of cited papers is more closely related to each other (has a thicker edge connecting them) the more frequently they are co-cited by other papers. Additionally, the size of a given article's vertex is determined by the sum of the weights (thicknesses) of the edges joining it. Therefore, the most prominent articles in the figure are those most frequently cited jointly with others. Thus, it can be said that these are the papers that constitute the main axis of research in each subject area, and it is worth noting that the leaders of the co-citation ranking created in this way do not always coincide with the most cited papers shown in Table 1.

It is also worth noting that the most frequently co-cited pairs of articles do not always include the article that leads the co-citation ranking. This indicates that some articles achieve a high ranking not by having a particularly strong relationship with any single article, but rather by being co-cited with many different articles.

The ranking of the most frequently cited pairs of articles is shown in Table 2, where the articles that lead simultaneously in the ranking of total co-citations are marked, and their positions in this ranking are indicated in parentheses.

Table 1. Top 15 cited works.

Title	Citations Collected	Topical Area
Transport reduction by crowdsourced deliveries—a library case in Finland	93	Other
Supporting Digital Scholarship in Research Libraries: Scalability and Sustainability	69	Education
E-books in academic libraries: Challenges for acquisition and collection management	68	Collections
Cultural sustainability as a strategy for the survival of museums and libraries	68	Culture
Sustainability challenge for academic libraries: Planning for the future	62	Other
Teaching skills for teaching librarians: Postcards from the edge of the educational paradigm	60	Education
Adoption of information and communication technology (ICT) in academic libraries. A strategy for library networking in Nigeria	40	Information and ICT
How to choose a free and open source integrated library system	39	Information and ICT
Bridging the digital divide: The role of librarians and information professionals in the third millennium	38	Information and ICT
Convergence of digital humanities and digital libraries	38	Information and ICT
Preservation research and sustainable digital libraries	38	Information and ICT
When the evidence is not enough: Organizational factors that influence effective and successful library assessment	36	Other
Public libraries as an infrastructure for a sustainable public sphere: A comprehensive review of research	33	Other
Developing knowledge innovation culture of libraries	32	Information and ICT
Changing roles of reference librarians: The case of the HKUST Institutional Repository	32	Collections

Another perspective on the issue is presented through Sankey diagrams. As mentioned, each citing article was assigned a research discipline according to the ASJC classification. This allows for the aggregation of cited (i.e., providing inspiration) and citing (i.e., drawing inspiration) papers. The most significant relationships are illustrated in Figure 7, with the subject areas of cited papers on the left and the ASJC codes of citing papers on the right side.



Figure 6. Co-citation network.

Table 2. Top 10 co-cited work pairs.

Work Pair Titles
Personal librarian program for transfer students: an overview A boutique personal librarian program for transfer students
Library collaboration with large digital humanities projects Supporting Digital Scholarship in Research Libraries: Scalability and Sustainability (2)
Moving beyond collections: Academic library outreach to multicultural student centers Libraries and student affairs: Partners for student success
Copyright literacy in the UK: Results from a survey of library and information professionals Copyright literacy in finnish libraries, archives and museums
Public libraries as an infrastructure for a sustainable public sphere: A comprehensive review of research (4) Public libraries as public sphere institutions: A comparative study of perceptions of the public library's role in six European countries
A call for sustainable library operations and services Sustainability challenge for academic libraries: Planning for the future (1)
Smart and sustainable library: Information literacy hub of a new city Public libraries as anchor institutions in smart communities: Current practices and future development
Supporting Digital Scholarship in Research Libraries: Scalability and Sustainability Convergence of digital humanities and digital libraries (10)
Convergence of digital humanities and digital libraries Laying the foundation: Digital humanities in academic libraries
Assessment in North American research libraries: A preliminary report card When the evidence is not enough: Organizational factors that influence effective and successful library assessment

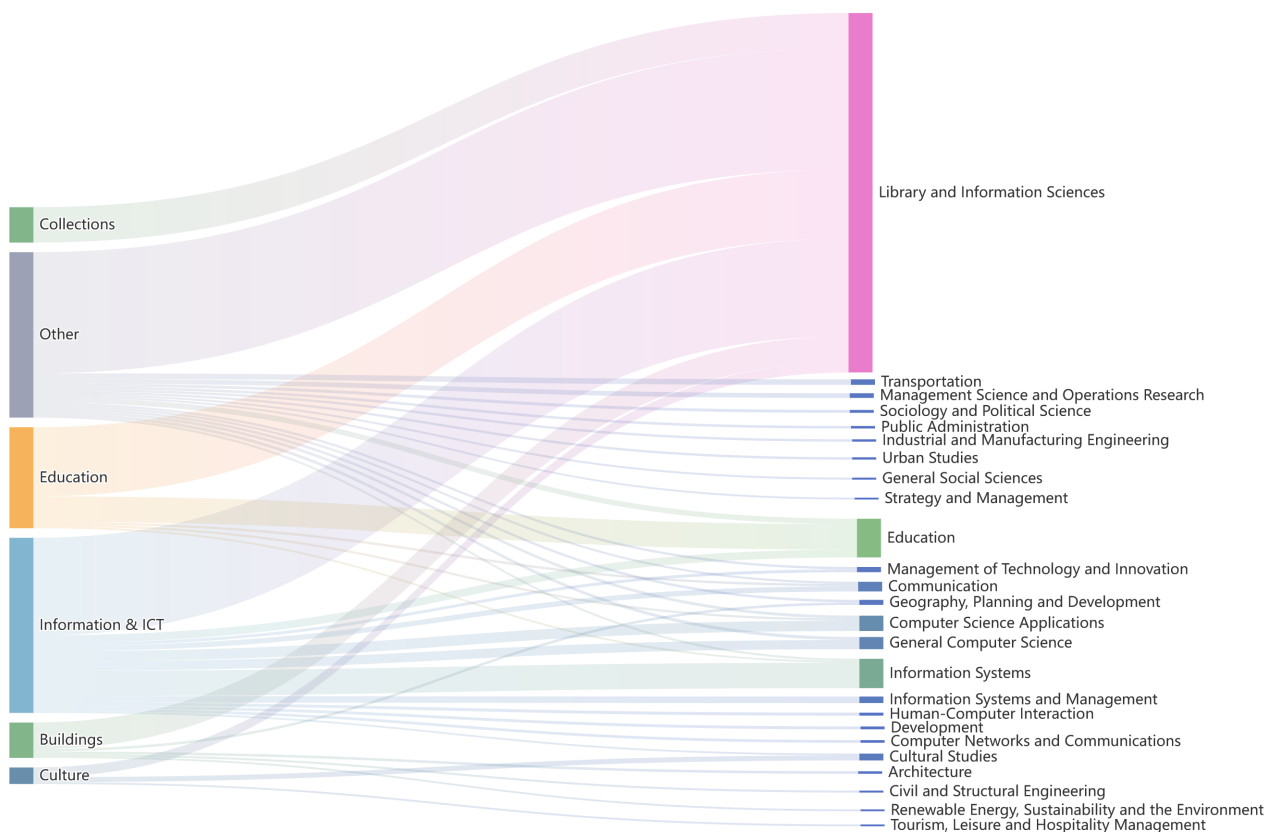


Figure 7. Citations flow by fields (cited topical areas on the left, citing ASJC disciplines on the right).

5. Limitations of the Study

This study has certain limitations that should be acknowledged. Firstly, the selection of a specific citation database may introduce potential biases and limitations. Alternative databases, such as Web of Science or Google Scholar, could provide different results and expand the scope of the analysis. However, it is commonly ascertained that each of the most important bibliographic data sources has its strengths and weaknesses. Scopus is yet generally considered to be more comprehensive than Web of Science, whereas Google Scholar is criticized, i.e., for inclusion of non-verifiable citing sources and the occurrence of duplicate citations (see [44–49]).

The geographical bias and multilingualism inherent in the choice of Scopus as the data source could slightly distort the results as well. This is due to the fact that databases like Scopus primarily index articles in English, which might overlook some relevant research published in other languages or from regions where English is not the dominant language of academic publishing. However, we believe this impact is relatively minor, as English remains the primary lingua franca in the scientific community. Additionally, we did not impose any language restrictions in our search queries, and Scopus does index articles written in other languages, with their titles and abstracts translated into English. This practice helps to reduce potential biases and ensures that a broader range of research is included in the analysis.

Secondly, the diachronic approach relies on available citation data, meaning that more recent publications might not be fully represented in the analysis. This limitation could affect the understanding of current trends and developments within the field.

Additionally, the study is limited to analyzing citations between printed scientific works, overlooking other forms of scholarly communication, such as social media platforms. Excluding these sources may lead to an incomplete understanding of the broader scholarly discourse on the topic.

Furthermore, the analysis focuses on the quantitative aspect of citations, without considering the qualitative (i.e., linguistic and cognitive) context in which they occur. This limitation restricts the interpretation of the impact and influence of specific publications within the field.

Lastly, it is important to note that the study's findings are based on the assumptions and research design chosen by the authors. Alternative research approaches or methodologies could yield different results and interpretations.

Nonetheless, the choice of the Scopus database appears to be appropriate for conducting a quantitative citation analysis. The diachronic approach is also well-established in the literature, which, in turn, allows for a qualitative interpretation of the obtained numerical data. This interpretation will be the focus of the next section.

6. Discussion

The discussion of the results obtained was carried out according to the previously stated research questions and was divided into subsections corresponding to each of them.

6.1. The Lifecycle Perspective (Q1)

Scientific publications' lifecycle is a common term to describe their citation history. Such a history is usually shown as a chart that relates the age of a publication to the number of citations it has received. Several basic types of lifecycles were proposed as early as 1979 by Aurel Avramescu [50]. The cycles reflect the strength of influence that a publication has on the thought of the authorial community active in selected areas of knowledge. The assumption which underlies the concept of tracking lifecycle is that the citation behavior of researchers can be explained by means of the so-called normative paradigm operating within the sociology of scientific knowledge (see, e.g., [51–60]). The possibility of determining quantitative characteristics of citation histories can be then the basis for drawing qualitative conclusions as to a flow of information between some specific entities (e.g., authors, journals, fields of knowledge, scientific institutions, or countries).

The presumption that the lifecycle of publications discussing sustainability-related issues within the LIS domain can reveal insights about the subdiscipline itself has been supported by numerous studies. Some examples have already been given in the Background Section of the present paper; among other examples, we can enumerate, e.g., [61–63]. More specifically, the theoretical framework adopted in this paper, linking the concept of sustainability to the lifecycle of publications addressing the topic, takes the form of the concept that the citation history of a group of certain documents sheds light on the rate of progress of knowledge in a given discipline and provides an additional, broader opportunity to understand the nature of scientific communication that has formed within the field under study.

Moreover, the same assumption also constitutes the basis for further reasoning, especially for answering questions Q2–Q4. That is to say, it is necessary to accept that the cited work makes some kind of intellectual (conceptual, methodological, contextual, etc.) contribution to the content of the citing work (see, e.g., [64–66]). It is only then that a bibliometric analysis of any body of scientific literature becomes meaningful.

The lifecycle examined using Finardi's method indicates a rapid progression of knowledge in the area of sustainable LIS. In particular, it is faster than the progress typical of most of the humanities and social sciences, i.e., the maximum is reached in the second or third year of the cycle. It thus resembles cycles characteristic of most of the natural sciences and engineering (hard sciences as opposed to soft sciences). It is especially evident when one assumes a sufficiently high level of aggregation of empirical data (e.g., [67–69]).

The same is demonstrated by the value of the diachronous cited half-life index for the sample analyzed, which is equal to 4. That is, half of all publications from the sample set, that were cited in the later literature, were no more than 4 years old at the time of the citation. Price's index value—i.e., the percentage of cited publications that are at most 5 years old—is also high, as it amounts to 0.66.

The aforementioned difference between hard and soft sciences is oftentimes expressed by contrasting the categories of theoretical sciences (pure sciences) and applied, or experimental sciences (see e.g., [70–78]). It can be therefore hypothesized that the content of works on sustainable LIS is predominantly devoted to experimental, methodological, and empirical issues, as opposed to purely theoretical or observational topics, which generally remain informative for longer period of time.

The type of lifecycle detected in the authors' study also suggests that, in cases of the sustainable LIS domain, the standard 2-year impact factor (IF) is a good approximation of their actual impact (cf.: [79]), since the 2-year citation window is able to capture the moment of the publications' highest citedness. On the other hand, the 5-year IF introduced by Thomson Reuters in 2007 covers the maximum citedness period as well as a part of the downward phase of the citation history. A suitable alternative—perhaps even better than the 2-year IF—is the 3-year citation-window-based SNIP index used in the Scopus citation index (see e.g., [80,81]), or the 4-year citation-window-based CiteScore index used in the same database (see e.g., [82]). The cycle expires around the 15th year of a publication's life, although citations become sporadic from around the 10th year. In research practice, this indicates that publications 10 years old and older are already falling outside the current scientific discourse. It can be caused, e.g., by the loss of the subject relevance or other factors, that were described i.a. by Line and Sandison in 1974 [83].

The regular shape of the observed cycles, the lack of large fluctuations between adjacent values of the histogram (which is presented in the form of a line graph to increase readability—see Figures 3–5), and the steady decline in citations referring to increasingly older papers may also indicate that the discipline of sustainable LIS is already well established, and the period of its formation has passed. Researchers have at their disposal a large stock of potentially citable papers published year after year, which may translate into the aforementioned lack of fluctuations. Publication activity shows an upward trend (cf. [6]) and the dynamics of citations is also on the rise (see Figure 5). However, this growth is not as rapid as it is in completely new, emerging research areas where there is a significantly lower number of publications and all of them are published within a short period of time.

Differences in the quantitative levels of citedness of individual subject areas can be attributed to differences in the number of publications belonging to these areas. A greater number of publications in a given set increases the likelihood of the average publication being noticed and cited by some authors. Therefore, the citation counts were standardized, which allowed for the normalization of differences between the lifecycles of papers belonging to various thematic streams (Figure 4). Nevertheless, the citation peaks are still found in the 2nd–3rd year of the publications' life in all areas except for the “Buildings” and “Culture” categories. In these subdisciplines, it is reached later, namely in the 8th and 4th year of the cycle, respectively.

To be more precise, for the “Buildings” category, the citedness of 4-year-old publications is minimally higher than that of 8-year-old works, as shown in Figures 3 and 4. Two distinct points of the maximum are clearly discernible there, and they are separated by only a scant decrease in the number of citations.

“Buildings” is by far the most specific area of research undertaken within sustainable LIS. Its subject is split between the technical sciences (architecture, urban planning, and civil engineering), and the social sciences (sustainable functioning of a facility in a social environment). The specialty termed as “Culture” is, in turn, close to the humanities (cultural and social anthropology, ethnology), but also visual arts and media studies. The distinctiveness of the “Buildings” and “Culture” subdisciplines can therefore be presumably attributed to their highly interdisciplinary thematic scope and to the fact that not only LIS specialists publish in these areas. Likewise, the journals in which papers are published do not necessarily belong to the LIS field, which may influence the delayed reception of such content by the library science community.

The cycle of the “Buildings” subdiscipline (Figure 3) is prolonged and not very dynamic, but is also relatively stable. A possible explanation for such slow decline and, on

the other hand, late reception of the publications' content could be the fact that the first condition for citing a publication is that it must be found and evaluated by the citing author. It may mean that members of the technical and engineering sciences community come across the sources of this type after a while and possibly by way of serendipity (see, e.g., [84]).

The citation dynamics of the "Culture" subdiscipline is diminishing faster than in the cases of the other specializations. This seems to indicate that new content here is displacing content previously considered central to the subject matter more quickly. The vibrancy of the development of the subdiscipline "Culture" also seems to be confirmed by the final increase in citations, i.e., the increase seen after 2018, which distinguishes this domain against the background of the remaining ones (see Figure 5). It is in fact the most rapid increase observed among all the thematic areas, which raises the idea of an exceptionally strong intensification of the work taking place within this research field.

It is also worth mentioning that "Culture" is the youngest of the specialities present in sustainable LIS and only became established around 2001 (see e.g., [12]). This factor is presumably stimulating and results in a sort of attractiveness of cultural issues, being a certain novelty in the discipline.

The short, although fairly intense, lifecycles observed for the "Collections" and "Other" categories (Figure 4) suggest that the ideas present in these groups of publications have already been exploited, and there has been a need for new proposals to be put forward for discussion. An alternative reason for the rapid extinction of the initially numerous citations may also be the fact that the "Collections" group has a very narrow thematic profile. This is because it is strictly and exclusively a librarianship topic, which is why it is difficult to expect citations that come from outside library science-oriented sources. The limited number of publications potentially citing such works may prevent extensive reception and widespread awareness even of the very existence of articles addressing library collections problems.

The "Other" group is characterized by a very high thematic heterogeneity, and yet its lifecycle shows a far-reaching similarity to that of the "Collections" category. It cannot be ruled out that the "Other" subdiscipline's structure is a convolution of minimally, averagely, and highly attention-grabbing topics, and thus not uniformly cited publications. Some of them may be cited as soon as they appear, and some others only after a certain period of time, depending on the subject and citing habits prevailing in a discipline that citing publications belong to. The curve observed in the form of the cycle of this entire heterogeneous group would then be a resultant of such a composition.

The category "Information and Communication Systems (ICT)" is dominated by topics connecting computer science and information science. However, the lifecycle of the examined sample deviates significantly from the lifecycle of the average document belonging to any of these two fields. The observed citation maximum is located in the third year of the cycle, whereas in the computer science literature, it falls much later (see, e.g., [85–87]). Similarly, in the case of information science the process of accruing new knowledge takes longer, since researchers typically rely on older literature (see, e.g., [88,89]). The development of digitization and the spread of open access publishing practices, which results in the increased accessibility of old publications (see, e.g., [90]), is sometimes pointed to as a possible reason for the retardation of the scientific literature aging process.

Interestingly, these patterns are also corroborated by Zhang and Glanzel, according to whom Price's index value in the fields of "computer science/information technology" and "education and information" between 1992 and 2014 fell from 0.49 to 0.32 and from 0.399 to 0.27, respectively, [91].

Only the period of declining of citedness, which can be observed after the 3rd year of the cycle and which is relatively sharp, may bring to mind a certain analogy with the rapidly aging natural sciences and technology, although not necessarily with computer science itself. It seems, therefore, that the type of cycle observed in the present study is so

individual that it cannot be directly related to any type of lifecycle seen in the disciplines on which the ICT branch is based.

“Education”, as another offshoot of the sustainable LIS discipline, can be placed close to the subdisciplines “Collections” and “Other” due to the very early citation maximum falling in the second year of the cycle (see Figures 4 and 5). However, when the period of decline following the point of maximum is considered, “Education” resembles more the “Information and ICT” category, i.e., the period is prolonged and slowed down. Rapid attainment of the moment of maximum and the slow decline of further citations makes this subdiscipline the most active one. The similarity of the late citation history stage to the analogous characteristics of the “Information and ICT” category could be attributed to the large share of IT issues in the field of education. The COVID-19 pandemic forced schools and universities to move into a remote education mode, which necessitated the wider use, development, testing, and evaluation of various competing computer technologies, IT tools, and other software used for educational purposes. The sharing of experiences in this area probably accounts for a large proportion of publications in the field of educational theory and practice, in which libraries, and their staff with its competences, have also played a role.

What also draws attention in Figure 5 is the steady and stable increase in the citation level of all thematic categories that make up the entire sustainable LIS discipline. The beginning of this increase can be traced back to around 2015, and if one excludes “Culture” and the slight decrease in citations for the “Education” group between 2015 and 2017, this date can in principle even be postponed to 2010. So it seems that the sustainability problems discussed in the LIS field are gaining a wider audience and importance in the scientific community. By extension, the contribution of LIS to more general sustainability issues is beginning to penetrate other fields of knowledge, which is analyzed in detail below.

6.2. Dynamics of Development of LIS Research Areas (Q2)

An alternative approach to citation analysis—yet one which is commonly used in investigating the rise and fall of popularity of certain topics in science—is the assessment of the number of articles dealing with the topics. This aspect of the development of the sustainable LIS discipline has already been summarized by the authors in their earlier work (see e.g., [6]). It was shown that the subdiscipline most represented in terms of number of publications (articles, conference proceedings, chapters in monographs) is “Information and ICT”, which accounts for 33% of all papers within the research sample. This was followed by categories termed as “Other” (28%), “Education” (17%), “Buildings” (11%), “Collections” (7%), and “Culture” (4%).

When, on the other hand, one looks at the number of citations received collectively by all publications belonging to the same areas, which can be taken as the scale of the resonance caused by them in the scientific community, the order is somewhat different. The highest number of citations per publication was recorded for the “Culture” category (6.6 citations), followed by, respectively, “Education” (5.8 citations), “Collections” (5.45 citations), “Information and ICT” (5.13 citations), “Other” (4.99 citations), and “Buildings” (4.01 citations).

There is a clear lack of consistency between the rank order of the individual subdisciplines, with the sole exception of the “Education” group, which is ranked 3rd in terms of the number of publications and 2nd in terms of citations. The sharpest contrast, however, is apparent in the case of “Culture”, which has the lowest number of publications and at the same time the highest average number of citations.

It is also often the case that, among the publications constituting a research sample, there is a certain subset of works that are not cited at all within the time period chosen for analysis. In the case in question, this subset is smallest for the “Other” category (75.4% of publications were not cited). The “Culture” group ranks second (77.8%), followed by “Buildings” (78.5%), “Collections” (83%), “Education” (84.3%), and “Information and ICT” (87%).

The speed of the first citation is sometimes considered to be a predictor of future high citation rates and a differentiator for early identification of valuable papers (see, e.g., [92,93]). Considering such an indicator, the category “Other” is in the lead. As the initial cut-off year of the analysis is 1994, the first citation appeared here as early as 1995. The category “Culture” was not cited between 1994 and 1997, and is closely followed by “Education”, which began its lifecycle one year later, i.e., in 1998. In contrast, there were longer delays for the thematic groups “Information and ICT”—where the first citation occurred in 2001—“Collections” (in 2003), and “Buildings” (in 2007).

A final—and the only complementary—type of indication of the scientific rank of a given topic in the area of sustainable LIS can be a list of 15 most cited articles belonging to the considered set of publications (see Table 1). The most obvious data that seem to be applicable to this subsection are the position on the list and, secondly the number of such hot papers belonging to the specific issue stream. As far as the first type of indication is concerned, the prominent categories are “Other” (this includes the article with the highest citation in the entire sample, which is a case study), “Education”, “Collections”, and “Culture”. In terms of the second criterion it is primarily “Information and ICT”, which clearly dominates the other categories both in the list of the 10 publications with the highest citation count (it appears here 4 times) and when the list is extended to 15 such publications (in which case, it appears there 6 times). However, this information is far too sparse to make any generalizations on its own and can only be used as an auxiliary factor that could further support conclusions drawn from indicators of a different type.

On the basis of the above five correlations, it can be tentatively concluded that the most prospective subdisciplines are “Culture”, “Education”, and (albeit with some reservations) the subdiscipline termed “Other”. At the opposite end of the rating scale are the categories “Buildings” and “Collections”. The area of “Information and ICT”, on the other hand, deviates from the characteristics exhibited by both extremes and is difficult to categorize unambiguously. It can therefore be said to lie somewhere between the most forward-looking area and the area with a declining trend, at least in light of the indicators used.

The above conclusions seem best motivated in the case of the subdiscipline “Culture”, which ranks among the highest in three of the five indicators used. For the category “Education”, the position in the rank hierarchy is only slightly less prominent. However, an additional argument may be the nature of the lifecycle to which it is subjected, which was discussed above.

The category “Other” requires separate treatment due to its thematic specificity and heterogeneity. First of all, this category includes review articles, which generally have extensive bibliographies and are therefore considered to be cited disproportionately often compared to articles of other types (see, e.g., [53,94–96]). In the present study, among the 240 papers comprising the entire “Other” category, there were 21 review articles that received a total (up to and including 2022) of 155 citations, giving an average of 7.4 citations per such article. Compared to the average citation rate for the entire “Other” category (4.99 citations per article), this result is clearly better, which in general confirms the above-mentioned regularity. Nevertheless, the “Other” category in terms of average citedness proved to have a low ranking—only “Buildings” had a lower citation rate than it, but at the same time, it ranked first in terms of first citation speed and showed the lowest percentage of publications that were not cited at all. With regard to the number of publications it was only surpassed by the “Information and ICT” group. It cannot be ruled out that both the outstanding first citation rate and the low percentage of papers not cited at all are attributable to some particular subgroup of the whole category, for example, to case studies as a type of empirical research, which were previously found to be of a type that has a significant ability to attract citations (cf. Table 1).

Within the framework of this article, this method was used to answer the question of which specific issues come to the forefront of research (constitute the so-called research front) within the individual subdisciplines of sustainable LIS (Figure 7).

The categories “Collections” and “Culture” are the least represented in Figure 7, making it difficult to draw justified conclusions about leading research trends in these areas. However, it is notable that within library collections research, the management of digital resources—particularly e-books—holds some prominence. Additionally, there is significant attention on fostering cooperation between libraries and multicultural student centers. The discussion of sustainability in the context of cultural preservation acknowledges the importance of conserving heritage; however, it must also consider the inherent challenges in balancing preservation efforts with existing resource constraints. Effective sustainable practices in cultural preservation require a nuanced approach, one that integrates limited resources while safeguarding cultural assets for future generations. This balance is critical to ensuring that preservation initiatives remain viable and meaningful over time. A more detailed exploration of sustainable practices in cultural preservation is provided in authors’ previous paper [6].

In addition, a group of publications with an “Education” orientation focuses on libraries’ support for “science 2.0” (see, e.g., [97]) and its sustainability dimension, libraries’ involvement in the development of sustainability-related curricula, as well as ways to raise awareness and “information literacy” levels of sustainability knowledge among students.

Leading research trends in the “Buildings” subdiscipline are the possibilities of making library facilities environmentally friendly, especially in terms of architectural design and energy saving, and thus a green approach to the overall planning, operation, and future prospects in library activities. While buildings play a crucial role by offering essential physical spaces, their primary purpose lies in creating secure and accessible environments that facilitate learning and foster community engagement. Within this context, sustainability should be framed as a supportive mechanism that enhances these core functions, rather than as an objective that might take precedence over them. Emphasizing sustainability in this way underscores its value in advancing safety, accessibility, and inclusivity within educational and community-oriented spaces. The authors’ previous article [6] sheds more light on this topic.

“Information and ICT” is characterized by a somewhat broader problem scope of its research front. This includes models for sustainable digital libraries, digital humanities, the role of access to information in the transformation of developing countries, co-creation of smart communities, and sustainable aspects of the development of scientific information as a discipline.

The heterogeneity of the “Other” category is also reflected in the co-citation data for its constituent articles. The range of issues covered here is equally heterogeneous and includes, among others, the role of libraries as public institutions in supporting the sustainable development goals of societies, methodologies for assessing the progress of libraries towards becoming an institution embedded in the sustainable development movement, sustainable aspects in the practice of organizing the work of libraries, case studies that can serve as examples or models for other library institutions in terms of implementing sustainable initiatives in everyday practice.

6.3. LIS Domain Contribution to Other Branches of Science (Q3)

Based on Figure 7 it can be stated that, in general, all LIS subdisciplines show quite considerable variation in terms of the scale of citation in fields outside of LIS, although the main “beneficiary” of the output produced by sustainable LIS is in all cases its parent discipline, i.e., LIS itself.

The subdiscipline “Collections” is the only one that has not received a single citation from outside LIS itself, which may seem understandable given its strictly librarianship specificity. On the other hand, in an era of widespread digitization and computerization, from which librarianship is no exception, one would expect that certain issues concerning, for example digital objects and collections, metadata, or open access, would find resonance in disciplines outside of LIS. One may wonder about the reason for such an insular approach, especially as it is not so much the digital collections or objects themselves that are

being discussed, but a sustainable approach to their creation, storage, and management, which seems to have implications for higher education and science institutions, other public institutions, and even commercially oriented institutions. It remains to be assumed, therefore, that such communications take place through channels other than scientific publications. These could be, for example, technical reports for internal use, conferences not indexed by the Scopus database, government regulations, or standards published by authorized bodies. Alternatively, assuming that the demand for information on the sustainability of digital sources comes mainly from practitioners (computer scientists, software engineers, students, and trainees, company managers, etc.), rather than academics, it can be hypothesized that downloading, reading, and following certain guidelines does not necessarily result in formal citation.

The next least influential subdiscipline outside of LIS itself is “Culture”. In this field, issues of preserving, consolidating, and safeguarding cultural heritage for future generations, mainly by means of their digital reconstruction, are highlighted. In the cultural aspect, one can also talk about the use of information systems to promote, enrich, and manage cultural institutions, e.g., museums, art galleries, libraries, etc. Based on Figure 7, it is possible to identify only two disciplines other than LIS drawing on its output, which are “cultural studies” and “tourism, leisure and hospitality management” with the influence on the latter being weaker.

The lifecycle and other quantitative indicators that were used to answer Q2 yielded a picture of the subdiscipline as very dynamic and developing; meanwhile, on the other hand, it is apparent that it is severely limited in terms of the extent of its impact. The lack of broader links with other disciplines may indicate that the area of culture studied in sustainable LIS is highly self-contained, i.e., its subject matter is so specific that it is not translatable into objects of study common in other disciplines, or that it has not yet managed to find any concepts that would bridge the gap between cultural sustainability and other SDGs. However, since it is generally assumed that all four pillars of sustainable development are interlinked somewhat by definition (see, e.g., [98–100]), it seems that it is only a matter of time before such links are found and connection is made with a wider range of other fields of knowledge. From this perspective, it can be that the current exuberance of the field of “Culture” is to some extent the result of its ongoing consolidation and the crystallization of certain leading ideas or conceptual frameworks in which there will eventually be a complete integration of the social, environmental, and economic dimensions of sustainable development studied in the LIS.

SDGs that could be mapped to this specific research orientation are target no. 8.9 (“By 2030, devise and implement policies to promote sustainable tourism that creates jobs and promotes local culture and products”) and target no. 12.b: “Develop and implement tools to monitor sustainable development impacts for sustainable tourism that creates jobs and promotes local culture and products”.

Some other SDGs that seem to be in line with the nature of the research carried out in this area are also goals no. 4.7 (“By 2030, ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and of culture’s contribution to sustainable development”) and target no. 11.4 (“Strengthen efforts to protect and safeguard the world’s cultural and natural heritage”).

The impact of the “Buildings” category on the external disciplines becomes apparent to a greater extent. Above all, strong links with engineering disciplines with an environmental focus are perceptible here (assuming increasing order of strength of influence): “Renewable energy, sustainability and the environment”, “Civil and structural engineering”, “Architecture”, and “Geography, planning and development”. The nature of these interdisciplinary links derives quite directly from the subject matter of the research carried out within the branch in question. These are, namely, issues related to spatial planning, the architecture

of buildings and interiors and ways of reducing their negative impact on the environment, energy consumption, and the carbon footprint generated by library information and communication infrastructures, and the environmentally friendly modernization of library buildings, etc.; meanwhile, in the areas of engineering and technical sciences, these issues are probably nothing new—narrowing them down and transferring them to LIS certainly opens up new research-interpretation possibilities and at the same time requires appropriate adaptation of the approaches and methods used so far. At the same time, however, as can be seen from the analysis of lifecycles, instead of increased dynamics, a certain stability and regularity of progress in this field of research has been noted in its case. Such a characterization seems consistent with the need, signaled above, to “break through” the disciplinary barrier and obtain LIS-derived concepts into the consciousness of the range of specialists associated with the technical sciences. However, this hypothesis does not apply to the citations received from the LIS community, which quantitatively—as Figure 7 shows—still far exceed those coming from outside the LIS. Nevertheless, it is worth emphasizing that, in terms of quantity, citations of this group by publications belonging to the LIS are the least numerous compared to the other five subdisciplines. It is possible that it is these citations, being dominant, that make the lifecycle of the “Buildings” category similar to the cycles typical of the humanities and social sciences, i.e., lengthening and flattening it, which also translates into a higher ISI citing half life compared to the engineering sciences (cf. e.g., [101–103]). The atypical nature of the sustainable LIS subdiscipline in question furthermore includes the fact that putting into practice any recommendations or innovations described in publications requires significant funding and is time-consuming. Raising funds for such projects, as well as implementing them and then reporting on their results in subsequent publications, is presumably performed in the form of individual investments and projects. Perhaps, therefore, it is precisely this time-consuming and episodic nature of the initiatives that forms the potential subject of the content of publications, that partly determines both the nature of the lifecycles to which these publications are subjected and the degree of interdisciplinary links that can be discerned through bibliometric analyses.

The practical relevance of such papers lies primarily in their ability to contribute to the discussion on how society can advance toward achieving the SDGs, specifically goals 7 (“Ensure access to affordable, reliable, sustainable and modern energy for all”), 9 (“Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation”), 11 (“Make cities and human settlements inclusive, safe, resilient and sustainable”), and 13 (“Take urgent action to combat climate change and its impacts”).

In the case of the “Education” category, there are also few links to other disciplines, and apart from LIS itself, it is clearly dominated by “Education”, which stands apart from the subcategory itself, although it shares the same name in the ASJC classification. Further, “neighboring” disciplines are (according to decreasing strength of connectedness) “Communication” (including scientific communication), “Computer science applications”, and “Information systems”. It seems that, as with the interpretation of the lifecycle of the “Education” category, the type of connections noted can be attributed mainly to the increasing role of computerization in the educational process and the spread of remote education, the origins of which were well ahead of the time of the COVID-19 virus pandemic (see, e.g., [104,105]).

From this perspective, it can be argued that the leading purpose of publications belonging to the subdiscipline “Education” is to support the SDGs covered by the social and, in part, cultural pillar of sustainable development. This would be, in particular, goal 4 (“Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all”), goal 8 (“Promote sustained, inclusive, and sustainable economic growth, full and productive employment and decent work for all”), goal 16 (“Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels”), and goal 17 (“Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development”).

Analogous aspirations seem to guide publications classified as “Information and ICT”, as indicated by the high number of links to the same disciplines as the “Education” category. Moreover, Figure 7 shows that, excluding the general discipline of LIS, the disciplines of “Information systems”, “Computer science applications”, “General computer science”, and “Education” show the strongest cognitive links to “Information and ICT” of all those identified. The additional disciplines whose representatives cite works belonging to the group in question are: “Management of technology and innovation”, “Information systems and management”, “Human–computer interaction”, “Development”, “Computer network and communications”, and “Cultural studies”. As can be seen, there are only three disciplines here that do not belong to computer science in the broadest sense, one of which is a narrowly profiled management science discipline, one appears to be a highly interdisciplinary domain (“Development”), and one is clearly humanistic in nature (“Cultural studies”). Given the contemporary ubiquity of sustainability ideas, which have not omitted IT issues either (see, e.g., [106–108]), the links with the various specializations present within IT seem natural. The links with disciplines of a humanistic nature, on the other hand, are less obvious. However, computer science is nowadays as ubiquitous as ideas of sustainability, and its achievements find applications in almost every area of life (including the so-called digital humanities—see, e.g., [109]). It can be seen as a certain reference to the aforementioned goal 9 and goal 12 (“Ensure sustainable consumption and production patterns”). The discipline of “Development” then encompasses a whole range of different issues, from civilizational transformation in developing countries, the redefinition of the role of libraries in public spaces, and issues of fundraising for the implementation of certain types of innovations in various environments—e.g., the creation of medical information systems—to information management in urbanization projects or issues on the borderline between politics and administration.

The last subdiscipline, i.e., “Other”, has the highest number of “collaborating” disciplines of all six identified in the study, most likely as a result of its high thematic heterogeneity. The range of external citing disciplines extends from LIS, whose share in the set of citing publications is well over 50%, to (taking again the descending order of percentage share): “Transportation”, “Management science and operations research”, “Education”, “Sociology and political science”, and additional disciplines whose citation percentages are very close to each other. These are: “Public administration”, “Industrial and manufacturing engineering”, “Urban studies”, “General social sciences”, “Strategy and management”, “Communication”, “Geography, planning and development”, “Computer science applications”, “General computer science”, and “Information systems”. Notably absent so far are engineering disciplines, such as transport engineering, production engineering, operations research, and social disciplines such as sociology, political science, and public administration.

The above analysis can also be complemented by answering the question of the network of internal ties among the six sustainable LIS subdisciplines. It also contributes to a broader knowledge of the structure of scientific communication and to a better understanding of the nature of the research conducted in the analyzed domain. A tool that may prove helpful in realizing the research objective formulated in this way is again the co-citation analysis; its results are presented in Table 2.

Based on the aforementioned data, it appears that the subdisciplines occurring within sustainable LIS are relatively hermetic. Indeed, only two pairs of subdisciplines have been identified that seem to intermingle to some extent. These are “Information and ICT” and “Education”, for which the common point is digital humanities and learning 2.0 (“digital scholarship”), including digital libraries as platforms for accessing the resources needed for both types of endeavor. The second pair, on the other hand, includes (again) “Education” and the category “Culture”, where the cultural diversity of the student community can be seen as a bridge between the two.

It should additionally be noted that, in both of these cases, the strength of the connection is relatively weak. Among the ten pairs of papers most frequently co-cited, there were

only two pairs that established a convergence between “Information and ICT” and “Education” and one pair proving a tangent between the categories “Education” and “Culture”. All other pairs of co-cited papers were confined to a single LIS subdiscipline.

6.4. Overall LIS Landscape Emerging from Present Study (Q4)

The current state of the discipline of sustainable LIS, as seen through the lens of bibliometric analysis, can be summarized at several levels.

When the discipline is considered as a whole and the type of lifecycle of its publications is taken into account, it can be seen that the dynamics of this cycle indicate, on the one hand, that the subject of sustainability is relatively well entrenched in library science; meanwhile, on the other hand, certain characteristics of the cycles seem to indicate a rapid and multidirectional pace of development of the discipline. This pace results in a rapid obsolescence of the content being the subject of scientific publications. Alternatively, instead of obsolescence one may speak of systematic displacement of content older than a few years beyond the nucleus of current debate, the reasons for which may be found in the rapid growth of growth of new knowledge, the increase in the number of new publications available to researchers, and the shifting interests of representatives of the discipline into ever new directions. Taking into account the high degree of interdisciplinarity of sustainability issues (see e.g., [110,111]), it can be assumed that there is indeed a huge number of issues that could potentially become an object of interest for LIS specialists, and each time an original research object, hitherto unseen in LIS, is introduced into the field of researchers’ perception, the process of accumulation of knowledge and works on it starts from scratch, so to speak, pushing concepts already known and cognitively exploited to the background.

Nor should the possibility be overlooked that a certain acceleration in the pace of research and information exchange in scholarly communication is a result of the transition of science to the electronic environment, including the growing popularity of the open access movement. In other words, the increased accessibility to publications of all types via websites and scientific social networks, the immediate availability of early cite articles, the growing number of specialized bibliographic abstract and full-text databases, the practice of online conferences popularized during the COVID-19 pandemic, etc., appear to contribute to the acceleration of information transfer in science, which is reflected in the age distribution of cited publications and will be detectable in bibliometric studies. This phenomenon can be expressed differently by saying that scientific communication constitutes the “bloodstream” of science and can determine the pace of its progress (cf., e.g., [112,113]).

At the same time, a bibliometric evaluation of the entire scientific literature on sustainable LIS shows a certain duality. In terms of the pace of development and the location of the moment of maximum citedness on the timeline, sustainable LIS resembles the hard sciences rather than the soft sciences, even though it actually (with a few exceptions) belongs to the latter. In the case of the natural sciences and engineering, the relatively early citation maximum and the exponential (or quasi-exponential) rate of decline in the citation curve after the moment of maximum, is generally explained by the applied rather than theoretical nature of these fields, the predominance of experimental over descriptive or observational research, and the fast progress in the area of new technologies. The large role and large number of studies devoted to research methodology, which generally enjoy high citation counts is also a significant factor. Corresponding to this character of sustainable LIS are, to a certain extent, case studies, which are a variant of empirical research, and strong interdisciplinary links with applied computer science, as well as with architectural aspects of library buildings, their interiors, urban locations, and facilities in general, including, for example, water and electricity supply systems, which all play a role in sustainable development.

The uniqueness of sustainable LIS manifests itself, apart from the possibility of distinguishing within its framework a number of subdisciplines that are quite clearly isolated from each other (in terms of subject matter, methodology, and the authors’ disci-

plinary affiliations), also in terms of links with other—sometimes completely different from LIS—disciplines of science. These links become apparent in the perspective of a diachronous analysis of the citations that articles belonging to the examined domain receive from representatives of cultural sciences, administration, management, architecture and urban planning, transport, decision theory, many branches of computer science, energy, civil engineering, and environmental engineering, as well as sustainability science itself—which permeates all the mentioned disciplines and to some extent constitutes their common denominator.

To be more precise, sustainability science determines the research fronts present in the area of the individual subdisciplines studied and constitutes their cognitive link—this does not mean, however, that these fronts are indistinguishable from one another. Rather, it should be said that the research fronts are different views of the same ideas, or different aspects of one central concept that gives them all a common composition. This is, of course, sustainability, and if one can speak of any leitmotifs prevalent on the research fronts throughout sustainable LIS, these would presumably be issues relating to electronic scholarly communication, science 2.0, and e-learning, including the relationship between these three areas, as well as a general consideration of how to make libraries and their wider surroundings environmentally friendly and ‘sustainable’ in the organization of their structure, the initiatives they undertake, and the daily practices of their operation (see Figure 6). As shown in Figure 6, the concept of digital scholarship, digital libraries, and sustainable information and communication technologies constitutes some sort of a certain interrelated totality or, in other words, a certain thread that is common to many thematic areas, which are notably present within the range of sustainable LIS domain. It seems that the greatest emphasis has been placed on the ways in which digital libraries are designed and used, as well as on the behavior of users of such objects, which fit into the model of sustainability. The general impression that one can obtain from the analysis of the composition of Figure 6 is that digital libraries and digital collections are the empirical core, on which efforts aimed at making library facilities sustainable in not only environmental but also social terms are focused. In the perspective of the results of the realized study, digital libraries are thus, so to speak, a rallying point, where initiatives related to lowering carbon emissions, information management, organizational culture of libraries, raising user awareness, or storing digitized cultural artifacts intersect.

7. Conclusions

First and foremost, the authors of this paper found nothing in the literature that comprehensively analyzes the lifecycles of sustainable LIS publications. The issues most thoroughly examined using bibliometric techniques include the thematic structure of the sustainable LIS discipline, the degree of interdisciplinarity, the paths of its current developments, and the growth of publications over time. The flow of disciplinary information across geographical boundaries and, to a somewhat lesser extent, the international cooperation of researchers and institutions are also commonly studied topics. Thus, not only the problems related to the pace of development of the discipline as viewed through the prism of citations but also its impact on other fields of science and a comprehensive analysis of the opportunities available to LIS in achieving the individual SDGs remain underexplored.

The shape of the lifecycle of papers published in the discipline under study, along with the cited half-life and the price index calculated for them, shows greater similarity to cycles typically observed in the hard sciences than in the social sciences. This indicates a dynamic development of the discipline, during which older content is rapidly pushed out of the scientific community’s perception. It can also be inferred that sustainable LIS is a well-established discipline that has moved beyond the initial formation and consolidation of its research focus. Other factors, such as the growing importance of electronic scholarly communication, the open access movement, the types of research conducted (e.g., experimental studies such as case analyses), and the use of scientific literature by

practitioners that does not result in formal citations, likely also play a role in shaping the observed lifecycle.

The identified variations in the lifecycles of the analyzed literature suggest that the optimal citation window for measuring impact in sustainable LIS is a period of 3 to 4 years.

Based on certain factors—(i) number of publications in the specified subdisciplines, (ii) the percentage of uncited publications, (iii) the first citation speed, (iv) the average number of citations per article, and (v) the topics of the 10 highest-cited publications—“Culture” and “Education” can be identified as the most forward-looking subdisciplines of sustainable LIS. In contrast, “Buildings” and “Collections” show less developmental dynamics. “Information and ICT” is difficult to classify unambiguously and requires a different methodological approach, such as citation content and context analysis, to assess its potential more precisely.

It can be additionally pointed out that all subdisciplines occurring within the framework of sustainable LIS are relatively hermetic, i.e., their interpenetration is very weak and basically only concerns the areas of “Education” and “Information and ICT”, for which issues pertaining to digital humanities and “science 2.0” are a common part.

Based on the analysis of research fronts and the content of selected publications, it can be concluded that the social pillar is the dominant one in sustainable LIS. The environmental pillar also has a relatively strong presence, while the economic pillar is the least represented. These conclusions apply to all LIS subdisciplines identified by the authors of this paper, except for the “Culture” subdiscipline, where the cultural pillar naturally takes precedence. Although the environmental pillar receives considerable attention, it is also the most reliant on research from outside LIS, primarily from technical and engineering fields. In other words, while LIS has some capacity in this area, its contributions largely involve applying methods or proposals developed in other disciplines. In contrast, the social and cultural pillars are areas where LIS demonstrates originality and creativity, not just adopting external initiatives but also proposing and developing its own approaches. Especially, the social pillar seems to be the one whose significance is worth emphasizing. The sustainable dimension of LIS theoretical concepts enhances the collective efforts to promote information literacy among members of the general public and social minorities through elevated access to knowledge and knowledge management tools (e.g., digital databases, e-learning platforms, data mining techniques). Another factor that should be taken into consideration here is the continuous increase in public awareness of sustainability issues, which is to be accomplished by libraries’ initiatives like exhibitions, conferences, free courses, open meetings with stakeholders or political decision makers, providing room and resources for self-education, and so-called life-long learning for everybody. All of these activities are at the same time part of a broader process of adaptability of modern LIS to ubiquitous societal changes, which are taking place within the frame of sustainable development civic movement.

Although the vast majority of information exchange occurs within the discipline, there are strong and numerous connections with various other disciplines, some of which are significantly different in terms of subject matter and research focus. The only exception is the “Collections” category, for which no external citations were recorded outside of LIS. In contrast, the other LIS subdisciplines are linked to a wide range of external fields, spanning both the technical sciences, the social sciences, and humanities.

The “Buildings” subdiscipline has a noticeable impact on fields such as energy, environmental engineering, civil engineering, architecture, and urban planning. The “Information and ICT” subdiscipline influences various branches of computer science and education in its broadest sense, while the “Education” subdiscipline impacts communication sciences (including scientific communication), the interdisciplinary area of information technology applications, and information systems theory.

The “Culture” category, as revealed by the diachronic citation analysis, resonates primarily within cultural theory (mainly cultural anthropology) and tourism management.

The “Other” category is characterized by the widest spread of disciplinary links, which include ties to sciences such as transport, operations research, sociology, political science, and—on a somewhat smaller scale—public administration, production engineering, urban planning, management sciences, communication sciences, urban planning, and a few broader research areas in the field of computer science, e.g., computer applications or information systems. Such a large segmentation is naturally indicative of an overly dispersed research focus in the category under discussion. Only by subdividing it further and identifying narrower and more coherent subcategories will it be possible to explain the relationships involved more fully.

An intriguing next step in the research presented in this paper would be to analyze the actual contribution of the thematic areas discussed here to the achievement of various sustainable development goals. This analysis would likely require employing content analysis methods.

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