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An Application of Bradford's Law of Scattering for the Identification of Significant Journals of Institutional Repository Literature

Diksha Sharma*
Reenu Arti Thakur**
Sangita Gupta***

This paper addresses the application of Bradford's law in the literature published on institutional repositories. In this domain, articles were listed in 300 sources on the Scopus database during the study period from 2002 to 2021. The journal ranking table was prepared with the cumulative number of items, the verbal formulation was done, and the Bradford bibliograph was prepared to show the pattern of the distribution of published literature. The results present a percentage error of 4.6x102 and Bradford's graph shows a Groos droop which does not match Bradford's distribution. The principal subjects covered in this area are information systems and management, libraries and information sciences, and computer networks and communications.

Keywords: Bradford's law of scattering, Bradford's multiplier, Institutional Repository, Scopus.

0 INTRODUCTION

Scientific communication obtains visibility via various channels such as journals, theses, databases, institutional repositories, etc. Among the diverse sources of information, a journal is one of the most valuable sources of primary communication as well as recent trends and expansions in any particular domain.

* Department of Library and Information Science, University of Jammu, Jammu. email: dikshasharma9922@gmail.com

** Department of Library and Information Science, University of Jammu, Jammu. email: reenu_thkr@rediffmail.com

*** Department of Library and Information Science, University of Jammu, Jammu. email: sangitagupta@gmail.com

Journals are published in hard form (on paper) or soft form (online). These can be subject-specific or multidisciplinary and are available free of cost (open access), or on a payment/subscription basis (closed access). Some journals are subject-specific as they have close intimacy with a specific area of research work and are considered to be the core journals for that particular subject matter. However, the abundance of journals in the communication channels and their subscription expenditure make it difficult for an individual, organization, or organization/ institution to acquire all the related journals in a given field. Bibliometrics provides techniques for identifying the most relevant journals in a knowledge domain, as well as benefits for determining budgetary issues concerning journal subscription charges.

For this concern, the concept of core journals was proposed in 1934 by Samuel Clement Bradford, and is universally recognized as Bradford's Law of Scattering. The law of scattering was formulated based on an experiment by L. Jones in the Science Museum Library, London in 1933 which was originally published in Journal ''Engineering'' in 1934 and later Bradford published in a book entitled ''Documentation'' in 1948[1]. Bradford's law of scattering focuses on how the literature or the content of a knowledge domain is scattered or disseminated in the world of scholarly communication.[2,3]

The law states:

"If scientific journals are arranged to decrease the productivity of articles on a given subject, they may be divided into a nucleus of periodicals more particularly devoted to the subject and several groups or zones containing the same articles as the nucleus, when the number of periodicals in the nucleus and succeeding zones will be as 1: n: n^2, where 'n' is a multiplier"[4]

Additionally, it states that journals related to any specific field can be divided into three zones, containing an equal count of citations and an unequal number of journals. The Bradford mathematical relationship of the count of journals in the core zone to the middle zone is a constant 'n' and to the tail zone, the relationship is 'n^2', likewise stated as 1: n: n^2.

Researchers aptly needed journals in their study or interest areas, and the publications holding the higher number of articles and citations are considered vital sources or appropriately regarded as the core or nucleus zone. The application of Bradford's law supports the identification of core journals by dividing the total number of journals into three distinctive zones, where Zone 1, namely the 'nucleus zone', has core journals having the highest number of articles or citations, followed by Zone 2 (i.e., allied or middle zone) journals with a lesser number of articles or citations, and Zone 3 (i.e., alien or tail zone) journals with the lowest number of journal articles or citations.[5]

In the present scenario, an institutional repository characterizes the institutional academic achievements and serves as a marketing tool by showcasing scholarly activities, outlining the research output, and considerably

promoting open access and publishing. IR comprises grey and white web content, which is usually removed from the website in a matter of weeks. IRs momentously promotes scientific research and improves the visibility [6,7,8,9] of the academic output of the institutions[8] in the open access.[9] Hence, institutional repositories are significantly important and are needed by users or library professionals to know about the trends and most relevant publications in this domain. This study attempts to enlist the core journals in this knowledge domain, published in the Scopus database, based on their citations using Bradford's law of scattering.

1 REVIEW OF LITERATURE

Several studies were carried out to validate Bradford's law of scattering in various knowledge domains by extracting the bibliographic data from various indexing, abstracting, and citation databases like Web of Science, Scopus, the Indian Citation Index, etc.

Dhruba, Verma, Nazim, and Sarkar[5] check the relevance of Bradford Law and the Leimkuhler model in the literature of information sciences published in the Scopus database between 2001 and 2020. The literature was identified for core journals and divided into three zones based on articles and citations. Initially, a very high percentage error was observed which does not fulfill Bradford's law. Later, Leimkuhler model was applied and a negligible percentage error of 0.0092357% has been calculated which significantly fulfills the law.

Wagh, Gawande, and Wadalkar[10] noted the relevance of Bradford's law on scattering in the Home Science literature. The number of journals in each zone was found to increase by 4.67 referred to as the Bradford multiplier. The study concluded that Bradford's law has been satisfied in the Home Science literature and validated by the application of the Leimkuhler model.

Venable, Shepherd, Roberts, Taylor, Khan, and Klimo[11] collected data from the regional databases of the top 25 pediatric neurosurgeons in North America and Europe from 2009 to 2013. Bradford's law was applied to identify the leading journals in the domain of pediatric neurosurgery. Egghe's formulation and Bradford's verbal formulation were used to obtain the results. A list of the regional bias of nine leading journals has been found toward the most cited journal articles among pediatric neurosurgeons in North America and Europe.

A study conducted by Wardikar and Gudadhe[1] explores the relevance of the distribution of journals in the domain area of Library & Information Science by using verbal formulation and graphic representations of Bradford's law and further authenticated it by the appliance of the Leimkuhler model. Bradford's law was considered invalid for the dataset of related journals whereas the Leimkuhler model justified its validity by a small percent error which suggested a need for advancement or modification to Bradford's law.

Nash-Stewart, Kruesi, and Mar[12], used Bradford's scattering law to analyze the number of medical publications on acute otitis media and pneumonia available in Cochrane Reviews. Analysis of the results showed that Bradford's law of scattering was not useful for identifying basic journals in studied domain areas.

The studies were conducted to identify the core journals and verify the validity of Bradford's law of scattering in respective knowledge domains. No study was found that put to test the validity of Bradford's law in the field of research on institutional repositories and hence, this study was carried out. Hence, there is a research gap that needs to be addressed. The study's findings will enable the researchers to identify the core journals. It would be helpful for the library professionals in the selection and procurement of the most significant journals in this area and hence would overcome the monetary restrictions.

2 SCOPE AND LIMITATIONS OF THE STUDY

The current study applies the bibliometric analysis of research articles published in the knowledge domain of the institutional repository and are available on the Scopus database during the last two decades i.e., 2002-2021. This paper attempts to analyze the more significant journals in the institutional repository domain based on Bradford's law of scattering.

3 DATA COLLECTION AND METHODOLOGY

The data is retrieved from the Scopus database owned by Elsevier index a colossal of international journals to analyze research publications from the domain area of the institutional repository over the last two decades (2002-2021). The search string used for retrieving required raw data is (TITLE-ABS-KEY ("Institutional Repository") AND (LIMIT-TO (DOCTYPE,"ar") OR LIMIT-TO (DOCTYPE,"cp")) AND (EXCLUDE(PUBYEAR,2022)) AND (LIMIT-TO (EXACTKEYWORD, "Institutional Repositories") OR LIMIT-TO (EXACTKEYWORD,"Institutional Repository") OR LIMIT-TO (EXACTKEYWORD," DigitalRepository") OR LIMIT-TO (EXACTKEYWORD, "Repositories") OR LIMIT-TO (EXACTKEYWORD, "Digital Repositories") OR LIMIT-TO (EXACTKEYWORD, "Open Access Repositories"))) resulted in 954 articles. The CVS file was downloaded to collect data, then analyzed and tabulated using VOSvewier and MS Excel, to elucidate the:

i. Overview of research articles in the domain of IRs.
ii. Application of Bradford's law of scattering to the literature published on IRs.
iii. Key journals within the zones of the knowledge domain.

5. DATA ANALYSIS

5.1. Overview of research articles on IR.

Table 1 outlines the basic information of literature available in the Scopus database. It indicates that the overall period of the study involves publications from the year 2002 to 2021. A total of 945 research articles appeared in 300 journals. On average, 3.18 articles are published in a journal. 2019 is the most productive year with a maximum of 96 publications, and Library Philosophy and Practice hold the highest number of publications in the domain area of institutional repositories. Assorted literature is published in ten languages, where English is the prime language used in 911 publications. In addition, the literature demonstrates the multidisciplinary coverage as dispersed in ten different fields, contributed by 84 countries, with the highest contribution from the United States (271 publications).

Table- 1 Basic information

Period	2002-2021
Total no. of Sources	300
Total no. of articles	954
Total citations in this domain	4952
Average no. of Document/ Source	3.18
Average no. of Documents/ Year	47.7
Average no. of Citation/article	5.19
Most Productive Year (publication)	2019 (96 publications)
Most Productive Journal	Library Philosophy and Practice
Most Productive Country (number of articles)	United States (271 publications)

5.2. Application of Bradford's Law of Scattering to the articles published on IRs.

Bradford's law of scattering can be used to select the most appropriate research journal from the diverse variety of journals. An exhaustive ranking list of journals is prepared based on citations received by the articles, and cumulative citations are furnished for verbal formulation.

Based on citations received by the journal articles as shown in Table 2, sources are divided into three zones, i.e., nucleus zone, middle zone, and tail zone, each comprising one-third of the total number of citations. Zone 1 (nucleus) has the lowest of 9 journals with 125 articles and a total of 1620 citations (contributed 3 % of the total journals share, 32.71% of total citations share); Zone 2 (middle) includes 26 journals, comprised of 287 articles and 1817 citations (contributed 8.6% of total journals share, and 36.69% of the total citations share) which are more than the first zone and Zone 3 (tail) consists of 265 journals published 542 articles which is much more than the preceding zones but received lesser number of 1515 citations (contributed 88.3% of total journals share and 30.59% of the total citations share). Bradford's multiplier represents the relationship between the number of sources present in a zone and the number of sources in its preceding zone (table 3). The percentage error was calculated based on citation distribution in the three zones. It should be nominal and is the fundamental basis for the formation of three zones. In this study, Bradford's distribution in each Zone is 9:26:265, and the value of 'n' is 29.4, i.e., multiplier.

Therefore, 9: 9 x 13.25: 9 x13.5 x 13.5:: 1: n: n^2

= 9: 119.25: 1580.0625

Error Percentage = 9: 9x256: 9x256x256 = (1708.3125-300 /300) x100

= (1408.3125/300) x100 = $4.6x10^2$

In addition, it is evident from the results that there is a high percent error of $4.6x10^2$ and revealing that the data does not justify the Bradford law of scattering.

Findings = 1: n: n^2

Expected (E) = 1:3:9

Result (R) = 1:2.8:29.4

Therefore 1:2.8:29.4 '"1: n: n^2

The above verbal formulation state that the number of citations in each zone is increased by a multiplier of 29.4.

Table-2: Zones

Zone	Journals (%)	Articles (%)	Avg article/ journal	Citations (%)	Avg citation/ article	Avg citation/ journal
Nucleus	9 (3)	125 (13.1)	13.8	1620 (32.71)	12.96	180
Middle	26 (8.6)	287 (30.08)	11.03	1817 (36.69)	6.3	69.88
Tail	265 (88.3)	542 (56.81)	2.04	1515 (30.59)	2.7	5.7
Total	300 (100)	954 (100)	3.18	4952 (100)	5.1	16.5

Table- 3 Scattering of Journals and citations over Bradford's Zones								
Zone	**Number of journals**	**Share of journals**	**Cumulative number of journals**	**Number of citations**	**Cumulative number of citations**	**Share of citation**	**Calculated Bradford multiplies**	**Bradford multiplier**
1	9	3	9	1620	1620	32.71	1	1
2	26	8.6	35	1817	3437	36.69	2.8	3
3	265	88.3	300	1515	4952	30.59	29.4	9

5.2.1. Graphical Presentation of Bradford's Law of Scattering of Journals in IR literature

Figure 1 represents Bradford's graphs for journal distribution that should back up the verbal formulation by witnessing a certain degree of consistency in delivering scientific publications. Fig 1 presents the Bibliograph which is generated by calculating the cumulative citations and rank of journals. Distinguishing the distribution in three definite divisions, describing (i) the uplifting from the initial point (ii) between the parameters of the study with a considerable share of linear relationship, and (iii) tail-end, depicting the end of the curve but it is unfinished if Groos droop exists[5]. The graph does not show linearity in the long tail zone after a curve till the middle zone and hence does not validate Bradford's law of Scattering in the present study[10].

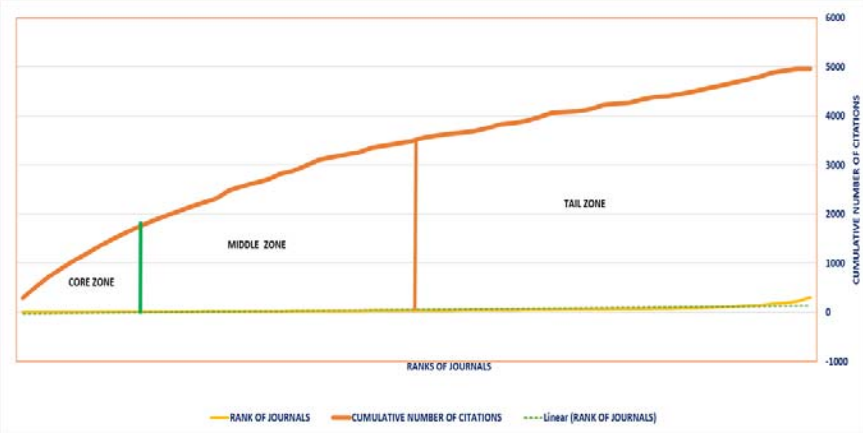

Figure 1 Bradford graphs for Journals distribution

5.2.2. Zone1: Ranked List of Core Journals

Core journals are regarded as the most relevant channels for publications in a specific area through which research results are shared to the maximum. Table 4 shows the list of core journals in the area of institutional repositories with the number of articles, h-index, and citations received from the titles covering the knowledge domain, and the publisher of the source.

'Journal of the American Society for Information Science and Technology,'

ranked at the top position published in the English language has an h-index of 150, 290 citations for 4 articles focused on Information Systems and Management; Library and Information Sciences; Computer Networks and Communications; Information Systems and published by John Wiley & Sons (United States). 'Lecture Notes in Computer Science,' published 37 articles and has the highest h-index i.e., 415, published by Springer in Germany. Journal ranked at 5 contributed only 1 and at 6 contributed 3 articles. A low number of articles in any journal cannot define its productivity; it merely predicts the quality of articles and their multidisciplinary nature. Such discrepancies can be observed in Table 4 showing the rank list of core journals Zone-1. Hence, other factors like impact factor and h- index need to be considered to know the relevance of the journals in the field.

Table-4 Core Journals

Rank	Journal Name	Articles	h-Index	Citations	Subject Coverage	Publisher and Country	Language
1	Journal of The American Society for Information Science and Technology	4	150	290	Information Systems and Management; Library and Information Sciences; Computer Networks and Communications; Information Systems	John Wiley & Sons (United States)	English
2	OCLC Systems and Services (now published as Digital library Perspectives)	35	23	225	Library Science	Emerald Group Publishing Limited (UK)	English
3	Library Hi Tech	13	20	204	Library and Information Sciences; Information Systems	Emerald Group Publishing Limited (UK)	English
4	Electronic Library	14	41	178	Library and Information Sciences; Computer Science Applications	Emerald Group Publishing Limited (UK)	English
5	Philosophical Transactions of The Royal Society A: Mathematical, Physical, And Engineering Sciences	1	174	158	Physics, Chemistry, Mathematics, Engineering, Earth science	The Royal Society	English
6	International Journal on Digital Libraries	3	34	151	Library and Information Sciences	Springer Germany	English
7	Malaysian Journal of Library and Information Science	7	26	148	Library and Information Sciences	University of Malaya (Malaysia)	English
8	Journal of Library Administration	11	29	138	Library and Information Sciences; Public Administration	Routledge (United States)	English
9	Lecture Notes in Computer Science	37	415	128	Computer Science and Mathematics	Springer (Germany)	English
	Total	125		1620			

5.2.3. Middle and Tail Journals

Tables 5 and 6 illustrate the journals in the middle and the tail zone respectively. The Middle zone has 26 journals ranked up to 30. English is the only language of publication in zone 2 while in zone 3 articles are available in multiple languages such as Bosnian, French, Lithuanian, English, etc. The prominent publishers in Zone 2 and Zone 3 are Routledge, Elsevier Ltd, Springer, SAGE Publications, Emerald Group Publishing, Taylor and Francis Ltd, etc. As we progress to Zone 3, the impulsive results show a disproportion in the number of articles published and citations received by each article which gradually decreases.

Table- 5: Zone 2- Middle

Rank	Name of the Journal	Articles	Citations	Publisher	Language
10.	New Review of Academic Librarianship	20	125	Routledge	English
11.	Serials Review	17	109	NA	English
12.	Cataloging and Classification Quarterly	11	108	NA	English
13.	Serials Librarian	29	93	NA	English
14.	Journal of Academic Librarianship	13	91	Elsevier Ltd	English
15.	Scientometrics	7	90	Springer Netherlands	English
16.	IFLA Journal	7	86	SAGE Publications Ltd	English
17.	IEEE Transactions on Learning Technologies	1	82	NA	English
17.	Journal of Information Science	4	82	SAGE Publications Ltd	English
18.	Library Philosophy and Practice	61	81	University of Idaho Library	English
19.	Journal of Librarianship and Information Science	5	70	SAGE Publications Ltd	English
20.	Library Review	9	67	Emerald Group Publishing Ltd.	English
21.	Journal of Digital Information	3	62	NA	English
21.	Journal of Informetrics	2	62	Elsevier Ltd	English
22.	College and Undergraduate Libraries	12	61	Routledge	English
23.	Conference on Human Factors in Computing Systems - Proceedings	1	55	NA	English
23.	Journal of Web Librarianship	8	55	Routledge	English
24.	Library Management	6	53	Emerald Group Publishing Ltd.	English
24.	Proceedings of the ACM/IEEE Joint Conference on Digital Libraries	17	53	Institute of Electrical and Electronics Engineers Inc.	English
25.	Digital Library Perspectives	16	52	Emerald Group Publishing Ltd.	English
26.	Program	6	51	Emerald Group Publishing Ltd.	English
27.	New Review of Information Networking	6	48	NA	English
28.	Aslib Proceedings	1	46	NA	English
29.	DESIDOC Journal of Library and Information Technology Defense Scientific Information and Documentation Centre	11	45		English
30.	Journal of the Association for Information Science and Technology	3	44	NA	English

Table -6: Zone 3- Tail (top 50-journals)

Rank	Journal Name	Articles	Citations	Publisher	Language
28.	Frontiers in Computational Neuroscience	1	43	NA	English
29.	ACM International Conference Proceeding Series	15	39	NA	English
32.	Science and Technology Libraries	4	39	Routledge	English
33.	Collection Management	3	36	NA	English
34.	Journal of Business and Finance Librarianship	2	34	NA	English
35.	Library Hi Tech News	6	32	NA	English
36.	Information Development	7	31	SAGE Publications Ltd	English
37.	IEEE Internet Computing	1	30	NA	English
37.	Library Collections, Acquisition and Technical Services	3	30	Taylor and Francis Ltd.	English
38.	CRIS 2006: Enabling Interaction and Quality: Beyond the Hanseatic League - 8th International Conference on Current Research Information Systems	3	26	Leuven University Press	English
38.	International Information and Library Review	8	26	Taylor and Francis Ltd.	English
38.	International Journal of Information Management	3	26	Elsevier Ltd	English
39.	Australian Academic and Research Libraries	2	25	Australian Library and Information Association	English
40.	Journal of Library Metadata	8	24	Taylor and Francis Ltd.	English
40.	LIBER Quarterly	3	24	Igitur, Utrecht Publishing and Archiving Services	English
41.	Communications in Computer and Information Science	18	23	Springer Verlag	English
41.	Journal of Electronic Resources Librarianship	4	23	Routledge	English
41.	Medical Reference Services Quarterly	5	23	Routledge	English
42.	Aslib Proceedings: New Information Perspectives	2	22	NA	English
42.	British Journal of Educational Technology	1	22	Blackwell Publishing Ltd	English
42.	International Journal of Information Science and Management	3	22	Regional Inform. Center for Sci. and Technol.	English

42.	Open Scholarship: Authority, Community, and Sustainability in the Age of Web 2.0 - Proceedings of the 12th International Conference on Electronic Publishing, ELPUB 2008	8	22	NA	English
43.	Journal of Scholarly Publishing	2	21	NA	English
44.	Information and Learning Science	3	19	Emerald Group Holdings Ltd.	English
45.	Information Services and Use	6	18	NA	English
45.	Online Information Review	6	18	Emerald Group Holdings Ltd.	English
46.	ACIMED	2	17	Centro Nacional de Informacion de Ciencias Medicas	Spanish
46.	International Journal of Metadata, Semantics, and Ontologies	4	17	Inderscience Publishers	English
46.	Journal of Convergence Information Technology	1	17	NA	English
47.	Profesional de la Informacion	6	17	NA	English
48.	Publications	7	17	MDPI AG	English
49.	African Journal of Library Archives and Information Science	3	16	Archlib and Information Services Ltd	English
49.	IEEE Access	2	16	Institute of Electrical and Electronics Engineers Inc.	English
50.	Behavioral and Social Sciences Librarian	2	15	NA	English
51.	Communications of the Association for Information Systems	2	14	Association for Information Systems	English
51.	ELPUB 2009 - Rethinking Electronic Publishing: Innovation in Communication Paradigms and Technologies - Proceedings of the 13th International Conference on Electronic Publishing	3	14	NA	English
51.	GL-Conference Series: Conference Proceedings	17	14	TextRelease	English
51.	Investigacion Bibliotecologica	3	14	NA	English; Spanish
51.	SAE International Journal of Passenger Cars - Mechanical Systems	1	14	SAE International	English

51.	IIiX 2010 - Proceedings of the 2010 Information Interaction in Context Symposium	1	12	NA	English
52.	International Nursing Review	1	12	NA	English
52.	Publishing Research Quarterly	1	12	Springer New York LLC	English
52.	Studies in Health Technology and Informatics	3	12	IOS Press	English
53.	Proceedings of the ASIST Annual Meeting	8	11	John Wiley and Sons Inc.	English
54.	VINE	2	11	NA	English
55.	Annals of Library and Information Studies	4	10	NISCAIR	English
55.	Iberica	1	10	NA	English; Spanish
55.	Proceedings - The 7th IEEE International Conference on Advanced Learning Technologies, ICALT 2007	1	10	NA	English
55.	Proceedings of the 7th International Workshop on Middleware for Grids, Clouds and e-Science, MGC'09 held at the ACM/IFIP /USENIX 10th International Middleware Conference	1	10	NA	English
56.	Community and Junior College Libraries	1	9	NA	English

6 DISCUSSION AND CONCLUSION

Bradford's law is used to identify core research journals spanning the years 2002–2021 on Scopus. Using the verbal formulation, nine journals found in the core signify their explicit domain nature. The core journals have comparatively more citations and an inconsistent and lower number of articles than the middle zone, signifying their implicit behaviour. However, twenty-six journals structure the middle zone and niche, allowing a wider array of research and audience. These journals may contain a small number of high-citation articles and are usually interdisciplinary and inclusive in nature. This further indicates a lower number of journals with a higher number of impactful articles in the middle zone, predicting their tapered/disciplinary nature. Henceforth, the decline in productivity from zone 1 to zone 3 is described by Bradford's law[11] nevertheless the verbal formulation does not satisfy Bradford's law of scattering as there is a huge percentage error that can't be ignored. Hence, the literature on the Scopus database does not satisfy Bradford's law of scattering in this subject domain. Similar findings are reported by many researchers[11] who concluded that the citation database did not fit the formulation of Bradford's

law[13,14,15]. The inconsistency in data related to journals could be attributed to the disparity between our findings and the projected zonal distribution[14], as well as the multidisciplinary nature of the knowledge domain[16,17], and is likely to be more dispersed. Further, exhaustive research is required to study the interdisciplinarity nature of literature and its impact on the spread of scientific information. Moreover, some technical issues may exist and cause inconsistency in retrieving bibliographic data. Some of the important reasons that may affect the results are entries for some authors or publications that don't meet the parameters defined for the study or the Scopus database exporting only 160 rows of records and eradicating the duplication of references.[13] Analysis of the results showed that Bradford's law of scattering was not useful for analyzing the scope of the literature on every discipline, or for identifying important journals. However, we can confirm the worthwhileness of the journal with their high impact factors or h index. Finally, we propose the top five journals in this domain are the *Journal of The American Society for Information Science and Technology, OCLC Systems and Services (now published as Digital library Perspectives), Library Hi Tech, Electronic Library, and Philosophical Transactions of The Royal Society A: Mathematical, Physical, And Engineering Sciences.*

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