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Application of Bradford's law of scattering and Leimkuhler model to information science literature

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This paper discusses the theoretical aspects of Bradford's law, its implications in different subject areas, various implementation forms, and its relevance in the published Information Science literature. The study attempts to apply Bradford's law and Leimkuhler model on Information Science literature to a total of 213 source items listed in the Scopus database during the study period of 2001 to 2020. A ranking table of journals and articles has been prepared to contain the cumulative count. In the first phase, the verbal formulation or the laws' algebraic form is employed in the journal distribution pattern that depicts a very high percentage of error in the actual observation that does not comply with Bradford's distribution. The Leimkuhler model's application follows this after finding the Bradford multiplier (k) value, thereby estimating the number of journals in the core and the successive two zones (r_0, r_1, r_2). A minor percentage error of 0.0092357% has been observed, followed by the graphical depiction of the data, i.e., "Bradford's Bibliograph." "Scientometrics" (39), "Bulletin of the Medical Library Association" (33), "Canadian Journal of Information and Library Science"(26) were found as the most preferred journals with the highest frequency.

Keywords: *Bradford's law of scattering, Leimkuhler model, Information science, Bradford's multiplier, Bradford's bibliograph, Scopus.*

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1. Introduction

Information Science is an emerging interdisciplinary subject in the knowledge domain that evolved and expanded from Library Science. Due to the extensive

application of Information and Communication Technology (ICT) in modern information engineering, this field of knowledge, known as Information Science in recent years, deals with the effective acquisition, storage, retrieval, and dissemination of information. Among the several statistical techniques, Bradford's law of Scattering is the most popular bibliographic concept describes science's functioning with mathematical tools and methods [1-2].

Bradford's law of Scattering provided the concept of 'Core Journals,' the law formulated by Samuel Clement Bradford in 1934 [1]. The research community frequently demands relevant journals due to proximity between the journals as per the concerned subject. The journals with more articles and citations are considered the core journals or journals in the nucleus. The journals in the nucleus contain the most relevant articles in any discipline [1].

The application of Bradford's law provides the information on core journals dividing the journals into three distinct zones, where Zone 1 contains the core journals with the maximum number of articles or citations, followed by Zone 2 (Allied), Zone 3 (Alien), and other alien zones [1-2]. The verbal formulation of the Bradford's law [1-2] and Leimkuhler model [3] is employed to test their applicability. Several studies have been conducted in different disciplines to test the validity of Bradford's law by extracting data from various citation and abstracting databases like Web of Science (WoS), Scopus, Indian Citation Index, and data from theses and dissertations of multiple subjects. No study has, however, tested the validity of Bradford's law in Information Science literature. Therefore, this study was conducted to apply Bradford's law of scattering and Leimkuhler Model to Information Science literature. The study's findings will enable researchers to know about the core journals of Information Science and help librarians select and procure the most relevant journals and avoid financial constraints.

2. Bradford's law of scattering

Bradford's law of Scattering represents a quantitative association among the journals and the papers published in these journals. The Chief Librarian at the London Science Museum, S.C. Bradford, performed a statistical interpretation of Geophysics' two bibliographies; "Current Bibliography of Applied Geophysics" (1925-1931) and "Quarterly Bibliography of Lubrication" (1931-1933). He inquired about the journals comprising the domains' references by decreasing productivity and dividing them into three nearly equivalent zones or sets; the first one profoundly productive zone (nuclear Zone), the second a moderately productive zone, and the third peripheral or low productive Zone. To calculate the number of titles in each of the three areas, Bradford has found regularity. Following the findings, Bradford settled that journal titles followed a familiar pattern in successive zones. The verbal formulation of Bradford claimed that if scientific journals were structured to lower productivity of publications on a specific issue, they could be distributed into the nucleus of publications of the discipline more precisely. Multiple groups (zones) bearing the same papers as the nucleus, where the number of periodicals in the nucleus and successive zones is as high as1:n:n^2 (n= multiplier) [1-2].

Bradford's research later enlightens Brookes [4] to propose the scattering aspect in the following linear relation, the most common wording of the Bradford Statute:

$$F(X) = a + b \log x \quad (1)$$

F(X) = Cumulative number of references in the first xmost productive journals

a, b = Constant

The verbal formulation was generalized in Vickery's interpretation which illustrates that it can be used to equal yield zones. The following simple function of Bradford's distribution implemented by Leimkuhler[3] named after him:

$$R(r) = a \log (1+br) \quad (2)$$

R(r) = Cumulative number of articles in journals ranked 1 through r

a, b = Parameter

Likewise, Brooke's [4] derivation for journal productivity appeared as:

$$R(r) = a \log \left(\frac{b}{r} \right) \quad (3)$$

3. Review of literature

Qio, Zhao, Yang, and Dong [5] reviewed Bradford's law's background, formation, developmental problems, and applications in detail. In this context, they have also interpreted the B.C. Vickery, F.F. Leimkuhler, B.C. Brooks and И.А. Смолъков's inferences in the law that leads to manifesting a unified idea about its primary content and evolving trend. The study further throws light on the method, central regions, conditions, and limitations of the application of Bradford's law.

Hjørland and Nicolaisen [6] argued about the absence of defining the term "subject" by Bradford and the applications of his law that may create confusion in identifying interdisciplinary and multidisciplinary branches of literature and affect the application in real-time. Thus, they have suggested three distinct types of scattering such as Lexical (denotes word), Semantic (denotes concepts), and Subject (denotes items applicable to a given task/problem) that would practically enrich the usefulness of the law.

The study of **Sudhier [7]** provided research contributions on the different aspects of Bradford's Scattering law, analyzing its theoretical aspects and applications in various subject fields, and finally applied to the literature in Physics using the citations of the doctoral theses submitted to the Indian Institute of Science. After calculating the Bradford's multipliers, the law applied to K's value as 1.2. The modification fits the Bradford's law for the data set when a multiplier for the first two zones (n=5) was calculated. The law did not match the journal distribution, considering the multiplier mean (13.4), and returned with

a percentage error of 68.66. Thus, using the Leimkuhler Model for verifying Bradford's law, the study established the validity with a minor 0.072% error.

Zafrunnisha [8] checked the validity of Bradford's law on 141 Psychology doctoral theses. She divided the journals into four groups to identify the core journals. "Journal of Applied Psychology" was identified as the most cited journal. The data set did not match either the law of Bradford or the Model of Leimkuhler.

Wardikar and Gudadhe [9] applied Bradford's Scattering law to the Library and Information Science literature (Ph.D. theses submitted to the Universities of Maharashtra, India) based on data from publications cited by doctoral students. Bradford's law of Scattering test includes 798 periodicals with 5467 references obtained from 138 theses from 1982 to 2010. The top-ranked publications with 207 citations were Annals of Library Science and Journal of Documentation, followed by College & Research Libraries (184) and Herald of Library Science (160). The study also revealed that one-third of the total citations were incorporated by each journal category, i.e., 15, 55, and 728, covered 1844, 1829, and 1794 articles, respectively. In the analysis, the relationship between each Zone was 15:55:728, which did not match Bradford's distribution.

Alves [10] applied Bradford's law on the 7272 WoS listed published literature of 2828 journals on the Capital Structure during 2014-2019 to analyze its influence in Corporate Finance. The paper identified 134, 531, and 2163 journals concentrating on 2387, 2262, and 2651 articles in three Zones.

Using the articles indexed in CABI and Indian Science Abstracts between 1965 and 2010, Tripathi and Sen [11] analyzed Bradford's law in Crop Literature. Leimkuhler Model was also tested, preparing a ranking list of journals, but the data set did not match Bradford's law even the Leimkuhler test was conducted.

Amsaveni [12] examined the relevance of Bradford's law of Scattering to the literature on Neural Network published in India from 2001 to 2015. The data (5209 articles and 58249 citations) was obtained from the WoS database. The study revealed that this law's theoretical formulation does not fit into the data set, but the Leimkuhler Model selections proved suitable for Neural Nsetwork literature.

Gourikeremath, Hiremath, Kumbar, and Hadagali [13] applied Bradford's law of Scattering over Microbiology research in India from 2002 to 2016. A total of 25,744 papers scattered in 328 journals published during the study period were retrieved from WoS. Data on annual output, relative growth rate, and doubling time of literature were analyzed, emphasizing time series analysis to predict future development. The Bio-resource Technology Journal is found as the most productive journal with 1,610 (6.25%) of the papers, followed by Applied Biochemistry and Biotechnology with 1,019 (3.95%) and 746 (2.89%) articles.

Nash-Stewart, Kruesi, and Del Mar [14] tested the validity of Bradford's law for Cochrane Review of Cochrane Library recognized pieces of literature on "Acute Otitis Media" (AOM) and "Pneumonia" following the method of extracting and grouping of randomized controlled trials (RCTs). The study broadly reflects Bradford's law but not that successful in predicting the literature size for a subject from the RCTs.

Kumar and Senthilkumar [15] reviewed Bradford's Scattering law on 18,877 research papers written by Indian scientists in Astronomy and Astrophysics domain between 1988 and 2017. The bibliographic data were collected from the WoS database, evaluated distinctly in different blocks consolidated for 10 and 30 years, and the core journals were was identified in Astronomy and Astrophysics. The Bradford's law of scattering and Leimkuhler Model were applied for testing the validity of the collected data. Due to the high concentration of papers in remarkably fewer journals, the literature scattering was not consistent.

Gayan and Singh [16] studied Chemistry's citation pattern (theses submitted to the central library of Tripura University) regarding those submitted to Shodhganga, the Indian ETD reservoir. Therefore, data from 20 theses consisting of 6214 citations were obtained from 2007 to 2016. Bradford's law was applied to identify the core journals in Chemistry, where Phytochemistry found the most-cited journal in the ranking list. The analyzed data set did not comply with Bradford's law but with Leimkuhler, and the Chemical journal's half-life was 12.6 years. The outcomes unveiled that the investigation would help chemical researchers concede the fields' attributes better, help librarians select resources, increase library collection, and help policymakers in decision-making.

Gautam and Verma [17] applied Bradford's law in Information Technology articles listed in Library and Information Science Abstract (LISA) from 2001 to 2014. A total of 1116 articles were covered in the study, and a ranking list was prepared.

Yang, Tseng, and Won [18] represented the Bradford's law on Data Mining literature indexed in Science Citation Index Expanded, Social Sciences Citation Index, and Arts & Humanities Citation Index from 1983 to 2013. The paper identified 25, 255, and 3271 journals concentrating on 5514, 5729, and 5446 articles in three zones. The USA ranked top as author country with 3959 articles, Chinese Academy of Sciences as the top author organization with 214 articles. The total number of articles raised high till the year 2013 except a fall in 2007.

Chaturbhuj and Sadik Batcha [19] studied the relevance of Bradford's law of Scattering on Fluid Mechanics' domain. The verbal formulation 1:n:has not fit with the data on Fluid Mechanics. Leimkuhler Model applied for verification of Bradford's law, and it works with 2:57:1462 geometric series with 0.005% of error. Other Scientometrics indicators such as DCI, ICI, author's ranking, and ranking of most preferred journals, the author's impacts are used for the qualitative and quantitative analysis of research output in Fluid Mechanics. The study also revealed that 13 highly contributed countries have international collaboration trends, T.E.Tenduyarwas the most productive author, and Chemical Engineering Science is the highest preferred journal in Fluid Mechanics.

4. Objectives Of The Study

The objectives of the study stated as:

i. To provide a journals' ranking list with the published articles and identify the core journals in Information Science.

ii. To examine the applicability of verbal (algebraic) formulation of Bradford's law and Leimkuhler Model in the literature published in the Information Science discipline.

5. Methodology

The study aims to analyze the relevance of Bradford's law of Scattering and Leimkuhler Model on Information Science literature for 20 years period (i.e., 2001 to 2020). The primary research data was collected from the Scopus database. Under the discipline of Information Science, an advanced search string ("Information Science" AND (LIMIT-TO (PUBYEAR, 2020) OR …. (LIMIT-TO (PUBYEAR, 2001)) was used to find out the raw data from the Scopus database and downloaded in CSV format. The ranking list of the journals and number of articles was prepared by using MS-EXCEL. Total 213 Journals were found during the substantial period. It was arranged in the descending order of articles' productivity and classified into three zones: Zone 1, Zone 2, and Zone 3, based on the total number of articles and citations received. The implementation of Bradford's law was done in three stages; the first verbal formulation is implemented, followed by applying the Leimkuhler Model and examining with the graphical interpretation. Finally, for outlining the graph, the cumulative number of journals' natural log value was determined.

6. Analysis and interpretation

6.1. *Ranking of Journals and Distribution as Zones*

Core Journal ranking studies are typically carried out to help select journals and assess a specific field's relevance for one or more journals. The journals' arrangement is ordered in descending frequency order where the journals with the highest publications are marked first, and the next is ranked second, and accordingly others. A total number of 665 publications were published in 213 journals during the study period (Table 1), and these were grouped into three Zones, namely Zone 1, Zone 2, and Zone 3. Zone 1 contains 12 journals (contributed 34.29% of the total articles); Zone 2 includes 42 journals (contributed 33.08% of articles), and Zone 3 consists of 159 journals (contributed 32.63% of articles). Out of 665 articles, the maximum number of articles (46) published in 2018, followed by 2016 and 2017 with 43 articles, respectively.

The USA, with 403 articles, is the country with the maximum number of articles, followed by China and Spain with 190 and 90 articles respectively. It is worth mentioning that India is ranked 5th with 41 articles that continue at the top of the developed nations like Canada, Germany, and Greece.

Table 1

Scattering of Journals and Articles in Different Zones

Zone	No. of Journals Share	% Share to Total Journals	% Share to Total Articles
1	12	5.63	34.29
2	42	19.72	33.08
3	159	74.65	32.63
Total	**213**	**100**	**100**

Table 2 shows the rank and frequency-wise list of 12 journals belonging to Zone 1. The journal "Scientometrics" ranked at the top with 39 articles. "Bulletin of the Medical Library Association" and "Canadian Journal of Information and Library Science" occupied the third and fourth ranks with 33 and 26 articles, respectively. "Education for Information" and "ACIMED" are ranked at fourth and fifth places with 23 and 22 articles respectively. This consolidated list of journal ranking indices could be beneficial to librarians, researchers, and LIS educators. Librarians can choose journals of higher significance and productivity in any specific field and address the budgetary constraints seen as a severe threat to their administrative responsibilities. Journals in the nucleus (core journals), i.e., journals in Zone 1, produce more articles with more citations than journals in the proceeding Zones, i.e., Zone 2 and Zone 3. Researchers of Library and Information Science can publish their research work in journals that produce the maximum number of articles with maximum citations from the ranking list of Journals given below:

Table 2

Core Journals in Information Science

Rank	Name of Journals	No. of Articles
1	Scientometrics	39
2	Bulletin of The Medical Library Association	33
3	Canadian Journal of Information and Library Science	26
4	Education for Information	23
5	Cuban Journal of Information on Health Sciences	22
6	Journal of The Medical Library Association	22
7	Revista Interamericana De Bibliotecologia	12
8	Investigacion Bibliotecologica	11
9	International Information and Library Review	10
10	Journal of Librarianship and Information Science	10
11	Library Philosophy and Practice	10
12	New Library World	10

6.2 Implications of the bradford's law

The following explications have been given, and outcomes show the accuracy of the journals' distribution with the verbal formulation of Bradford's law [1-2]. The first section of the analysis deals with the wording of theory based on data consisting of the entire journal references ordered in articles' descending frequency. In contrast, using the same data, the second section sketches the graphical representation.

6.2.1 Implications of the verbal formulation

The cited journals have been arranged by order of descending number of articles; accordingly, the journals' ranking, numbers of articles, and a cumulative number of articles were furnished for testing the verbal formulation of Bradford's law [1-2].

The algebraic representation of the law was tested in 213 journals grouped into three Zones. There are 12 journals in Zone 1, 42 Journals in Zone 2, and 159 Journals are in Zone 3. The percentage of journals, number of articles in each Zone, cumulative number of citations, and Bradford's multiplier are tabulated in Table 3.

Bradford's multiplier factor was calculated by dividing the number of journals in a Zone by the number of journals in its preceding Zone [1-2]. In this case, Bradford's multiplier is nothing other than the relation between the number of journals in a zone and the number of journals in the previous Zone. The percentage errors of citations distributed amongst the three zones must be minimal, which is the foundation of selecting three zones.

In the Table 3 data set, 218 articles were published in 12 journals, followed by 220 articles in 42 journals. The remaining 217 articles were appeared in 159 journals, meaning each journal category embraced one-third of the total articles. As per Bradford's law, approximately one geometric series in the form of 1:n: determines the Zones so named. However, in the current study, each Zone's relationship in Bradford's distribution is 12:42:159, where 12 represents the number of journals in the nucleus, and the value of 'n' is 13.25, i.e., multiplier.

Therefore, $12:12*13.25:12*(13.25)^2 :: 1:n:n^2$

12:159:2106.752277.75

Table 3

Scattering of Journals and Articles over Bradford's Zones

Zones	Number of Journals	Percentage of Journals (%)	Number of Articles	Cumulative No. of Articles	Bradford Multiplier
1	12	5.63	228	228	1
2	42	19.72	220	448	3.5
3	159	74.65	217	665	13.25
Total	**213**	**100**	**665**		

$$\text{The percentage error} = \frac{2277.75 - 213}{213} \times 100$$

$$= 9.694 \times 10^2$$

Because of the high percentage error, the data will not fit into Bradford's law.

Again, Table 2 describes the relationship of any Zone with the following equations:

$F = 1: n:n^2$ **'F'** = Finding

$R = 1: 3.5:13.25$ **'R'** = Result

$E = 1:3.5:12.25$ **'E'** = Expected Result

$\therefore$ 1:3.5:13.25 $\neq$ 1:n:n^2

Thus, it is evident that the above distribution does not comply with Bradford's law. Hence, it is needed to check the Bradford Scattering law [1-2] based on the Leimkuhler Model [3] as applied in the studies of Sudhier [7], Waridkar and Gudadhe [9], Gayan and Singh [16] to investigate the applicability for the calculation of non-cumulative rank frequency.

6.2.2 Application of leimkuhler model

In a Leimkuhler Model [3] for Bradford's distribution, the core journals with unique references in the first Zone are first determined, and the multiplier (k) of Bradford is measured. Leimkuhler Model is a size-frequency measure. Accordingly, the number of journals in the following Zones is counted with the multiples of Bradford's multipliers, and the multiplier (k) for Leimkuhler distribution is determined employing Egghe's mathematical method [20].

Following Bradford's verbal formulation, Leimkuhler's Model defined as:

$$r_0 = \frac{T\ (k-1\ )}{(k^p - 1)}$$

'T'= Total number of journals

'k'= Bradford's multiplier

'p'= Number of zones

In this analysis, the articles are distributed into three Zones so that the mathematical equation implements Bradford's law:

$$k = (e^y y_m)^{\frac{1}{p}} \qquad (4)$$

$$k = (1.781)^{\frac{1}{p}}$$

Therefore, Bradford's multiplier 'k' value is determined as:

y_m = 39(number of items in the most productive source)

p = 3 (number of zones)

$\therefore$ $\mathbf{k} = (1.781 \times 39)^{\frac{1}{3}} = 4.11$

$$y_o = \frac{A}{P}$$

'A' = 665 (Total number of articles)

'p' = 3 (Number of Zones)

So, $y_o = \frac{665}{3} = 221.67$

It is followed by calculation of r_o, and calculated as:

$$r_o = \frac{T\ (k-1)}{(k^p - 1)}$$

T = Total number of journals

p = total number of Zones

$$= \frac{213\ (4.11-1)}{(4.11^3 - 1)} = 9.68$$

$$\mathbf{A} = \frac{Y_o}{\log k},$$

Now, log k = 1.41, thus,

$$\mathbf{a} = \frac{221.67}{1.41} = 157.21$$

$$\mathbf{b} = \frac{k-1}{r_o} = \frac{4.11-1}{9.68} = 0.321$$

Thus, $r_1 = r_0 \times k = 9.68 \times 4.11 = 39.78$

$r_2 = r_0 \times k^2 = 9.68 \times (4.11)^2 = 163.42$

Therefore, the number of journals in the nucleus (r_0) = 9.68 (≈ 10), and
Mean value of the Bradford multiplier (**k**) = 4.11

Table 4

Leimkuhler Model of Bradford's Distribution in 3 Zones

Zone	No. of Journals	Cumulative No. of Journals	No. of Articles Share	Cumulative No. of Articles	% Share to Total Articles
1	10	10	208	208	31.28
2	40	50	228	436	34.29
3	163	213	229	665	34.44
Total	**213**		665		100

Hence, Bradford's distribution from the LeimkuhlerModel [3] represented as:

$r_0 : r_0 * k : r_0 * k^2$

$= 9.68 : 9.68 * 4.11 : 9.68 * (4.11)^2$

$= 9.68 : 39.7848 : 163.515528$

Adding all parts of the above ratio, we get 212.980328.

Therefore, the percentage error from the real count:

$$\textbf{\% error} = \{(213 - 212.980328)/213\} * 100$$

$$= 0.0092357$$

So, the error percentage is found to be 0.0092%, which is negligible from the calculation above. The findings for Bradford's scattering based on Leimkuhler Model are shown in Table 4, which indicates that the number of journals representing articles to all Zones expands with a multiplier of 4 approximately. The data's zonal analysis reveals that Zone 1 consists of 10 journals with 208 articles, Zone 2 consists of 40 journals that produced 228 articles, and Zone third, that consists of 163 journals produced 229 articles. As proved by Bradford, not one-third of the total articles are precisely generated by the three Zones. Zones 2 and 3 are closer to 33.33% article share, and the proportion of the number of journals is not quite the same.

6.2.3 Application of Bradford's law to the total number of Citations

The journal's impact is identified by the number of citations received by the articles of a journal. A journal may be highly productive, but it may not be the same as its impact is concerned. Maintaining quantity may not be capable of maintaining quality. So, the application of Bradford's law in the data set of citations is very significant. The journals are arranged in the descending order of citations. Bradford's multiplier is calculated, and the distribution is shown in table 5 to employ Bradford's law to the total number of citations.

Table 5

Scattering of Journals and Citations over Bradford's Zone

Zone	No. of Journals	Cumulative No. of Journals	No. of Citations Share	Cumulative No. of Citations	% Share to Total Citations	Bradford's Multiplier
1	12	12	1978	1978	38.78	1
2	42	54	1814	3792	35.56	3.5
3	159	213	1309	5101	25.66	13.25

A total of 213 articles have been grouped into three Zones to assess the law's algebraic interpretation, namely Zone 1, Zone 2, and Zone 3 (Table 1) and therefore, calculating Bradford's multiplier by dividing the number of journals between a Zone by the number of journals in its preceding Zone. The Table 5 data set shows that 12 journals in Zone 1 received 1978 citations, 42 journals in Zone 2 received 1814 citations, and 159 journals in Zone 3 received 1309 citations. As per Bradford's law, the Zones will create approximately one geometric series in the form of $1:n:n^2$ returns adverse results, as each Zone's relationship in the present study is 12:42:159, where 12 represents the number of journals in the nucleus. The value of n is 13.25, i.e., the multiplier did not match Bradford's distribution (as proved in section 6.2.1).

6.2.4 Graphical formulation

This step attempts to backs up the verbal formulation by witnessing a certain degree of consistency in delivering scientific publications. Figure 1 illustrates a logarithmic design with both the cumulative number of journal titles and citations on the horizontal and vertical axis, respectively. The plotted graph is introduced as "Bradford's Bibliograph" as it validates Bradford's law distribution depicts three definite realms, namely, (i) Rapid lifting from the grounding position (ii) Between two variables, a significant share of linear relation exists, and (iii) distribution's tail-end; a 'droop' is observed indicating incompleteness.

In any "Bradford Bibliograph" (see Figure 1), the core journals are identified as the points that lie at the graph's opening curved section before it tangentially converts to a straight line. At the top of the curve, the sloping part is called "Groos droop," that Brookes interpreted to symbolize the incompleteness of "Bradford Bibliograph."

7. Discussion

Information Science as a field of study expanded its range and evolving quickly, resulting in critical to providing relevant articles to the user groups associated with this discipline. Although the application of Bradford's law is a common area of research to different fields, no study has applied it to Information Science literature utilizing data from the Scopus database.

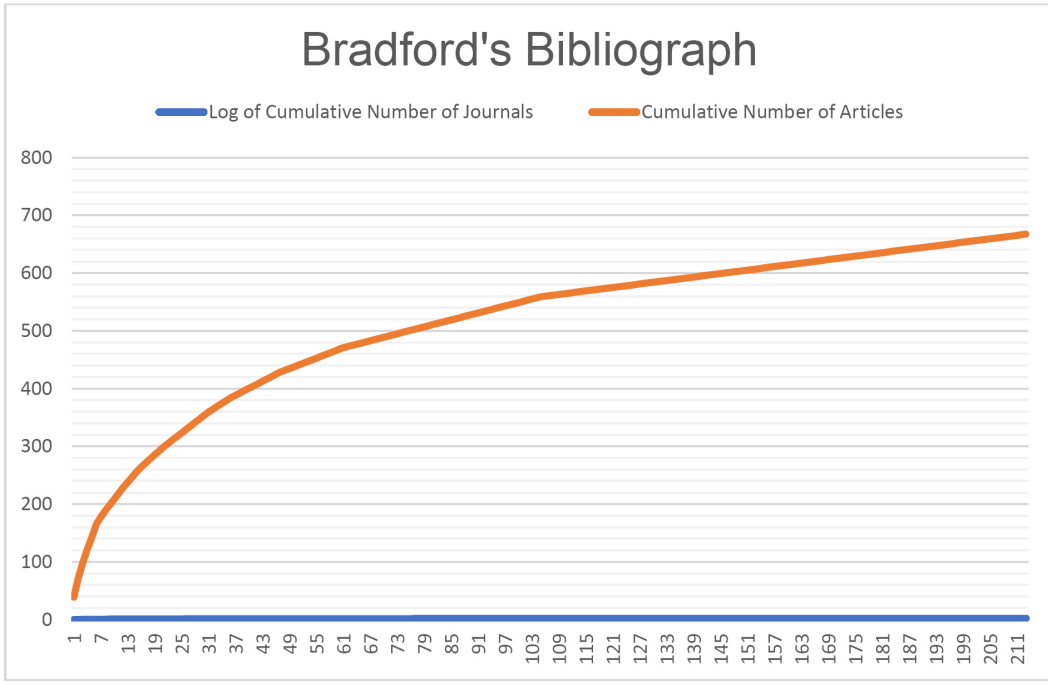

Figure 1

Bradford graphs for article distribution in Journals

The scope of the present study is not only confined to the identification of core journals in Information Science but to establish the validity of this law by using extensive mathematical techniques. The application of the verbal formulation with a Bradford multiplier of 13.25 identified 12 journals in the core (Table 2). Observation of high percentage error (9.69×10^2) and difference in calculated and expected analogy in the verbal formulation of Bradford's law is proved to be unfit in the data set. Most of the previous studies are seen to cease the application of this law at this stage. However, this study authenticates the Leimkuhler Model as expanded by Egghe [20], making it significantly different from the previous studies. This formulation evaluates Bradford's multiplier (k) and expected number of journals in the nucleus (r_0) to calculate percentage error in the expected number of journals. This formulation depends on applying exponential functions to predict the Zone-wise distribution, whereas there is hardly any mathematical formulation achieving statistical homogeneity to be applicable in all data sets.

Moreover, this study also tests Bradford's law in the data set for the total number of citations. The productivity (number of articles) and performance/impact (citations) are often analogous to the quality. A journal may be quantitatively in top order, but it may not be so qualitatively. Because of this difference, a separate test on the data set for source-citation distribution is performed, which is very significant in this context. As an authentic metric

for measuring performance, the citation is the mirror image of a source's impact in general and an article in particular. The journals in core Zone are highly cited than the journals in succeeding Zones as described by Bradford as "diminishing productivity" from Zone 1 to Zone 3. The fitness of Bradford's law and its implications of the source-citation distribution is different. The journals in the core are cited more than those in the succeeding Zones, indicating that the number of impactful journals (journals with more citations) is less than journals with lower impact. In addition, the scattering of journals and citations does not fit into Bradford's distribution.

Inferencing Leimkuhler Model to Bradford distributions, this concern would help the researchers identify the relevant journals covering Information Science literature and open up provisions for analyzing the literature distribution for the contemporary period of 20 years. Nevertheless, as the concerned domain is highly interdisciplinary, it is not easy to identify all the relevant topics under one broad heading. As suggested by Hjørland and Nicolaisen [6] that using different search terms from three distinct viewpoints, i.e., Lexical, Semantic, and Subject, would be an ingenious solution. Again, it can also increase the complexity of analysis, and the possibilities of alienation from the actual discipline cannot be ruled out. The present study has used only "Information Science" as the search term by keeping all these issues in mind. However, further research is required for indexing such recently simulated concepts that do not appear directly but are inclined to the same research area. For instance, concepts like Computational Linguistics, Data Integration, Knowledge Graphs, Lexical Semantics generally represent Linguistics and Computer Science; factually, they are all related to Information Science. Integrating such unique terms into the broader heading will pull out more related literature and journals that would help enrich researchers and future scientometric studies.

8. Conclusion

The distribution pattern of journals, articles, and citations on Information Science literature does not match $1:n:n^2$ Bradford's distribution pattern. When the law's verbal formulation or algebraic form is implemented, 13.25 has been found as the Bradford multiplier, which does not comply with the distribution due to the high percentage error $9.694 \times 10^2\%$). The Leimkuhler Model's implementation to validate Bradford's law determined that the law is legitimate for the data set, though a percentage error of 0.0092357% returned, which is almost negligible. Bradford's law implementation is a much popular area of Bibliometric analysis. Much research has been conducted to test its implementation in different data sets to discover the most contributing source in any discipline.

Nevertheless, hardly any data set is found to fit into Bradford's distribution perfectly. Relevance of Bradford's law in Information Science literature implies that the core journals, i.e., journals in the nucleus (Zone 1), have more articles than the journals in the peripheries (Zone 2 and Zone 3). Journals in the nucleus include "Scientometrics,""Bulletin of the Medical Library Association," and "Canadian Journal of Information and Library Science." Bradford's law implies that domain analysis is relevant because fewer journals are

in the core Zone than in the peripheral Zones. According to the Bradford distribution, the number of journals and articles in the given Zones is inversely proportional (Table 1), i.e., the number of articles decreases as the number of journals increases from Zone 1 to Zone 3.

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