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Application of Bradford's Law of Scattering to the Materials Science Literature: A study based on Web of Science Database

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Abstract - *The present paper tests one of the important bibliometric laws of Bradford's Law of scattering for the literature related to 'Materials Science' for the period 1995-2014 as available in the Web of Science Core Collection database. A total of 42,383 articles related to Material Science published in journals in English language during the study period are retrieved. The 42,383 articles are scattered in 465 journals. A list of ranked journals was prepared and it was found that the Journal of Alloys and Compoundswith 1,939 articles is the most productive journal publishing Material Science literature followed by Materials Letters of the Elsevier Science BVwith 1.146 articles and Materials Chemistry and Physics with 1,111 articles. In this study, theoretical aspects of Bradford's Law of Scattering are tested and found that the data do not fit to the present sample. The Leimkuhler model is tested and found to fit the data for the Bradford Multiplier (k) at 14.71. The Bradford law is alsotested through graphical formulation by drawing the Bradford bibliograph and is found to confirm all the three characteristics.*

Keywords: Bibliometrics, Bradford's Law of Scattering, Materials Science, Web of Science, Ranking of Journals

1. Introduction

In every field of research, there are some popular journals which are frequently referred and authors wish to publish in those journals because of close relationship with the field of research field and journal. These are referred as core journals. The identification of the most significant journals in a field has among its advocates faculty of various disciplines. Enthusiasts for the idea regularly attempt to define the boundaries of their disciplines by showing which journals are best, most prestigious, read, or most cited (Katherine, 2003). Librarians and library and information science educators have described various methods and purposes for developing such lists (Nisonger, 2007). Some of these correspond to the need to define a field's boundaries; others correspond to acquisition and retention needs.

There are several approaches for determining core journals some of them are subjective judgment, use, indexing coverage, overlapping library holdings, citation data, citation network/co-citation analysis, production of articles, Bradford's Law, faculty publication data, and multiple criteria methods (Nisonger, 2007). S.C. Bradford first coined the concept of core journals in 1934, which is popularly known by Bradford Law of Scattering. Bradford law of scattering describes how the literature on a particular subject is scattered or distributed in the journals. The law is based on an investigation performed in 1933 by L. Jones in the Science Museum Library, London. It was first reported in 1934 in the Journal ‘‘Engineering’’ by Bradford and subsequently in book entitled ‘‘Documentation’’ by the same author in 1948 (Bradford, 1948).

Among the several statistical expressions, Bradford’s Law of Scattering is perhaps the most popular and the best known of all the bibliometric concepts that try to describe the effective working of science by mathematical means (Mahapatra, 2009).

2. Materials science

Materials science, also usually well known as materials science and engineering, is an interdisciplinary subject field which deals with the discovery and design of new materials. This relatively new scientific field involves studying materials through the materials paradigm (synthesis, structure, properties and performance). It incorporates elements of Physics and Chemistry, and is at the forefront of Nano science and Nano-technology research (Tripathi, 2015).

The materials revolution, together with information technology and biotechnology is considered to be the major driving force of a new industrial paradigm. In order to maintain or create global competitiveness, all countries are interested in investing in R&D in this new area, with the hope of creating new industrial opportunities (Mohan, Gupta and Dhawan, 2003). India has also started major research programmes in the material science area, involving a large number of universities and research agencies.

In every field of research, there are some popular journals which are frequently referred and authors wish to publish in those journals because of close relationship with the field of research field and journal (Ram and Paliwal, 2014). These are referred as core journals. In case of Materials Science and Engineering fields the large number of journals is available for publication of research outcomes. The assignments of core journals in these areas are essential task for information science, to help the scientists to choose right journal for publishing pertinent research.

3. Review of Related Studies

Bradford's Law of scattering has been the main topicof many articles in LIS literature. Numerous formulations of the law have been proposed. The first notable paper on the law was that of Vickery (1948) and next paper by Kendall (1960). Then later Wilkinson (1972) discussed the bipolar nature of the law who proposed that verbal formulation of the law expressed Bradford's theory, while graphical formulation expressed his observation. The search for an exact formulation of Bradford's law stated by Vickery and Leimkuhler (1967) and was further followed by many other authors.

Although many studies have inveterate the rationality of the law, they often found that the value of the Bradford multiplier varies among subject's categories. On the application part, the studies of Sengupta (1990) and Goffman and Morris (1970) are noteworthy. Gupta (1991) studied the applicability of Bradford's law to citation data of Ethiopian medical journal. Other studies comprise Arjun Lal and Panda (1999) they collected data from 20 doctoral theses in Plant Pathology submitted to Rajendra Agricultural University, Bihar. The study conducted by Garg and Sharma (1994) of R&D indicators in Indian industry using Bradford's law shows that law is not only applied to scattering of publications but in other scopes also. Many scholars have studied the application of Bradford law in the various domains and this study on the Material Science literature is also significant study.

4. Objectives

The main purpose of this study intends to accomplish the following objectives:

- Identify the core journals that contain a substantial proportion of the total Materials Science literature with the reference to the Indian researcher.
- To study the phenomenon of scattering for citation data.
- To test the appropriateness of verbal and graphical formulation of Bradford's Law of Scattering.

5. Methodology

The data for the present study was collected from the Web of Science database of Thomson Reuters, UK. The research output covered in the Web of Science Core Collection database has been searched with the keyword as 'Materials Science' in the 'Title' for the period 1995-2014.It is found that the 465 journals have produced 42,383 articles and these 465 journals have been analyzed to test the Bradford law.

6. Bradford's Law of Scattering

Samuel Clement Bradford, a chemist and chief librarian at the Landon Science Museum, has made a statistical analysis of two geophysics bibliographies, the Current Bibliography of Applied Geophysics (1992-1931) and the Quarterly Bibliography of Lubrication (1931-1933).

Bradford Law of scattering is used as a tool to study the output of journals. It expresses the quantitative connection between journals where the journals are arranged in descending order of productivity and divided into equal zones. He defined the first zone as "nuclear zone", which is highly productive and a small number of core journals belong to this zone. The second zone is moderately productive, while the third zone is less productive. Where the number of periodicals in the nucleus and succeeding zones will be 1: n: n2, where n is a multiplier (Bradford, 1948). The observation of Bradford later described as linear relation by Brookes (Brookes, 1969) which is expressed as:

$$F(x)= a+b\log x$$

where, F(x) is the cumulative number of references contained in the first x most productive journals, and a and b are constant.

Again, Vikery (Vickery, 1948) extended the verbal formulation of the Bradford law to show that its application in any number of zones of equal values. Later on Leimkuhler (Leimkuhler, 1967) has given a simple expression of Bradford law that is later known by his name and it is expressed as:

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

Where, *R(r)* is the cumulative number of articles contributed by journals ranked 1 through *r*, and *a* and *b* are parameters. Similarly, Brookes derivation of journals productivity takes the form

$$R(r) = a \log(b/r)$$

Further, Wilkinson (Wilkinson, 1972) noticed that the formulae provided by Leimkuhler and Brookes did not describe the same phenomenon. Several other mathematicians provided different models but the Brookes and Bradford laws, however, gained more acceptance than others.

7. Theoretical Interpretation of Bradford's law

Bradford's law of scattering describes a quantitative relationship between journals and the papers they publish. It explains that only small number of journals will be needed to supply the nucleus of papers on given topic which accounts for a substantial percentage (1/3) of the articles, to be followed by a second larger group of journals that accounts for another one third, while a much larger group of journals picked up the last third.

There are two most widely recognized formulations of the Bradford's law: the verbal formulation which is derived from the verbal statement of Bradford's conclusion, and the graphical formulation, which is an empirical expression derived from the graphical survey of a distribution of periodicals.

Bradford did not give a mathematical model for his law. Models were suggested later by Brookes, Vickery and Leimkuhler. Several authors, while explaining the scattering of articles in journals, have formulated many different models of Bradford's law. Leimkuhler developed a models based on Bradford's verbal formulation.

(1) $$R(r)= a \log (1+br)$$
$$r = 1,2,3\ldots\ldots$$

While explaining Leimukhler's law, Egghe shows that

(2) $$a = Y_0 / \log k$$
(3) $$b = k - 1 / r_0$$

here r_0 is the number of sources in the first Bradford group

Y_0 – the number of items in every Bradford group (all these group of item being of equal sizes), and

k – the Bradford multiplier

$R(r)$ is the cumulative number of items produced by the sources of rank 1,2,3…r

a and b are constants appearing in the law of Leimkuhler.

In forming Bradford groups, it is shown that the number of groups p is a parameter that can be chosen freely.

Egghe (1990) has shown the mathematical formula for calculating the Bradford Multiplier *k as*

(4) $$k= (e^{y}\, y_m)^{1/p}$$

Where γ is Euler's number (e^{γ}=1.781)

If the sources are ranked in decreasing order of productivity, then y_m is the number of items in the most productivity sources.

Then y_0 and r_0 as follows

(5) $$Y_0 = y^2_m \log k$$ and
(6) $$R_0 = (k-1)\, y_m$$

Once p is chosen, the value of k can be calculated by using

$$k = (1.781\, y_m)^{1/p}$$

and

(7) $$Y_0 = A/P$$

where A denotes the total number of articles.

Let T denote the total number of journals in Bradford group, there are $r_0 k^{i-1}$ sources (i= 1,2,3...p)

(8) $$T= r_0 + r_0 k + r_0 k^2 + \ldots\ldots\ldots + r_0 k^{p-2}$$

(9) So, $r_0 = T/1+k+k^2+\ldots + k^{p-1} = T(k-1)/(k^p-1)$

Since A and $T$are known from the data set, $r_0$and $Y_0$are calculated, once p is calculated by the formula (7).

Gupta and Kumar (2001) have given the theoretical aspects of Bradford's law and they studied its applicability using the above method. According to Brookes (1979), to test the conformity of Bradford's law, one should meet three implicit conditions.

1. In dividing the journals in to zones, the number of articles in each zone must remain constant
2. The Bradford multiplier k must be greater than one.
3. The Bradford multiplier must remain approximately constant.

8. Analysis and Discussion

8.1 Top Ranked Journals

Core journals ranking studies are usually made to help in the selection of journals and in assessing the importance of one more journals in a particular subject field.

The journals are arranged in their respective descending order of frequency and in alphabetical order among the same rank number. The journal contributing the largest number of articles is ranked as number one, next as ranked two and so on. The criterion for ranking is purely quantitative not qualitative.

The ranked list of most cited journals of Materials Science literature in India is shown in the Table 1. In the analysis, the articles are distributed in 465 journals with a total of 42,383articles. From the Table 1 it is clear that *Journal of Alloys and Compounds*, an inter disciplinary journal in the area of Materials Science published by Elsevier tops the list with the highest contribution of 1,939 (4.57 per cent) articles. Materials Letters, also a publication of Elsevier, is in the second position by accounting 1,146 (2.7 per cent) articles, while Materials Chemistry and Physics, also published from Elsevier occupies the third position with 1,111 (2.62 per cent) articles. Of the top 30 journals of Materials Science literature, 23 journals have more than five hundred articles.

Table 1 Ranked list of Journals

S. No.	Journals	Country	Publisher	Rank	Count	%
1	Journal of Alloys and Compounds	Netherlands	Elsevier Science SA	1	1939	4.57
2	Materials Letters	Netherlands	Elsevier Science BV	2	1146	2.70
3	Materials Chemistry and Physics	Netherlands	Elsevier Science SA	3	1111	2.62
4	Journal of Physical Chemistry c	USA	Amer chemical society	4	1083	2.56
5	Journal of Nano science and Nanotechnology	USA	Amer Scientific Publishers	5	1079	2.55
6	Applied Surface Science	Netherlands	Elsevier Science BV	6	1069	2.52
7	Bulletin of Materials Science	India	Indian Academic Sciences	7	1036	2.44
8	Materials Science and Engineering	Switzerland	Elsevier Science SA	8	1014	2.39

	a Structural Materials Properties Microstructure and Processing					
9	Journal of Materials Science	USA	Springer	9	866	2.04
10	Journal of Magnetism and Magnetic Materials	Netherlands	Elsevier Science BV	10	823	1.94
11	Ceramics international	England	Elsevier Science Ltd.	11	792	1.87
12	Materials research bulletin	England	Elsevier Science Ltd.	12	783	1.85
13	Journal of materials science materials in electronics	Netherlands	Springer	13	756	1.78
14	Materials Design	England	Elsevier Science Ltd.	14	739	1.74
15	Langmuir	USA	Amer chemical society	15	683	1.61
16	Colloids and Surfaces b Bio interfaces	Netherlands	Elsevier Science BV	16	674	1.59
17	Crystal Growth Design	USA	Amer chemical society	17	647	1.53
18	Thin Solid Films	Switzerland	Elsevier Science SA	18	646	1.52
19	Materials and Manufacturing Processes	USA	Taylor and Francis Inc.	19	615	1.45
20	Journal of Crystal Growth	Netherlands	Elsevier Science BV	20	588	1.39
21	Journal of Non Crystalline Solids	Netherlands	Elsevier Science BV	21	515	1.22
22	Surface Coatings Technology	Switzerland	Elsevier Science SA	22	501	1.18
23	Metallurgical and Materials transactions a Physical Metallurgy and Materials Science	USA	Springer	23	500	1.18
24	Journal of Reinforced Plastics and Composites	England	Sage publications Ltd.	24	485	1.14
25	Indian journal of Engineering and Materials Sciences	India	National Institute of Science Communication and Information Resources (NISCAIR)	25	471	1.11
26	Optoelectronics and Advanced Materials Rapid Communications	Romania	National institute of Optoelectronics	26	469	1.11
27	Nanotechnology	England	IOP Publishing Ltd.	27	466	1.10
28	Journal of Nanoparticle Research	Netherlands	Springer	28	450	1.06
29	Journal of Materials Chemistry	England	Royal society of chemistry	29	444	1.05
30	Journal of the American Ceramic Society	USA	Wiley – Blackwell	30	440	1.04

8.2 Application of Bradford' law

In order to observe the appropriateness of the distribution of journals using the verbal formulation of Bradford law, the following explanations are made and the results are presented. The first part deals with the verbal formulation of the theory based on data consisting whole periodical references, arranged by their decreasing frequency of citations while the second part examines the graphical representations based on the same data.

8.2.1 Verbal Formulation

Table 2 presents details of highly productive journals to test the verbal formulation of Bradford's law. In the table, the rank, number of journals, Cumulative number of Journals, number of articles, Cumulative total of articles, log of Cumulative number of Journals are given to test the verbal formulation of Bradford's law.

Bradford's technique is used to group the journals in to three zones of productivity and Bradford's law of scattering is applied to test the verbal formulation.

The frequency of articles arranged from highest to lowest are presented in Table 2. In this study 14 journals covered 14,236 articles, next 31 journals covered 13,850 articles and the next 420 journals covered 14,297 articles. In other words, 14 journals covered one third of the total articles, the next 31 journals accounted for another one-third articles and the next 420 journals covered remaining one third.

The distribution of journals and corresponding number of citations in the three zones along with the value of Bradford's multiplier are shown in table 3.

According to Bradford, the relationship between the zones is 1: n: n^2, while the relationship of each zone in the present study is 14:31:420 which does not fit into the Bradford's distribution.

Therefore, the Bradford's formulation may be modified in the following way to suit the journal distribution pattern:

$$14: 13*2.21: 13*2.21^2*4$$

Substituting2.21=n, then

$$14: 14n: 14n^2* 4 \text{ which is } 1:n: 4n^2$$

Where, 14 represent the number of journals in the nucleus and n= 2.21 is a multiplier. Thus, the modified Bradford's law of scattering is testified. But here the multiplier calculated is for the first two zones, and for the third zone its value is found to be 4 fold.

The mean value of multiplier is 7.87

Therefore 14: 14*7.87: 14*7.87^2 :: 1:n:n^2

14: 110.18: 867.11 which is 991.29

$$\text{The percentage of error}= \frac{991.29-465}{465} \times 100 = 113.18\%$$

Here the percentage of error is high and the present data will not confirm the Bradford's Law.

Table 2 Productivity –wise distribution of Periodicals

Rank	No. of Journals	Cumulative no. of Journals	No. of articles	Cumulative total of articles	Log (n)	Zones
	1	1	1939	1939	0.00	I zone
	1	2	1146	3085	0.69	
	1	3	1111	4196	1.10	
	1	4	1083	5279	1.39	
	1	5	1079	6358	1.61	
	1	6	1069	7427	1.79	
	1	7	1036	8463	1.95	
	1	8	1014	9477	2.08	
	1	9	866	10343	2.20	
	1	10	823	11166	2.30	
	1	11	792	11958	2.40	
	1	12	783	12741	2.49	
	1	13	756	13497	2.57	
	1	**14**	739	14236	**2.64**	II Zone
	1	15	683	14919	2.71	
	1	16	674	15593	2.77	
	1	17	647	16240	2.83	
	1	18	646	16886	2.89	
	1	19	615	17501	2.94	
	1	20	588	18089	3.00	
	1	21	515	18604	3.04	
	1	22	501	19105	3.09	
	1	23	500	19605	3.14	
	1	24	485	20090	3.18	
	1	25	471	20561	3.22	
	1	26	469	21030	3.26	
	1	27	466	21496	3.30	
	1	28	450	21946	3.33	
	1	29	444	22390	3.37	
	1	30	440	22830	3.40	
	1	31	432	23262	3.43	
	1	32	427	23689	3.47	
	1	33	426	24115	3.50	
35	2	35	411	24526	3.56	
36	1	36	409	24935	3.58	
37	1	37	380	25315	3.61	
38	1	38	370	25685	3.64	
39	1	39	365	26050	3.66	
40	1	40	347	26397	3.69	
41	1	41	343	26740	3.71	
42	1	42	339	27079	3.74	
43	1	43	337	27416	3.76	
44	1	44	336	27752	3.78	

45	**1**	**45**	**334**	**28086**	**3.81**	
46	1	46	329	28415	3.83	III zone
47	1	47	325	28740	3.85	
49	2	49	320	29060	3.89	
50	1	50	313	29373	3.91	
51	1	51	310	29683	3.93	
52	1	52	305	29988	3.95	
54	2	54	255	30243	3.99	
55	1	55	247	30490	4.01	
57	2	57	245	30735	4.04	
58	1	58	243	30978	4.06	
59	1	59	241	31219	4.08	
60	1	60	238	31457	4.09	
61	1	61	233	31690	4.11	
62	1	62	230	31920	4.13	
63	1	63	229	32149	4.14	
64	1	64	228	32377	4.16	
65	1	65	226	32603	4.17	
67	2	67	219	32822	4.21	
68	1	68	214	33036	4.22	
70	2	70	211	33247	4.25	
71	1	71	206	33453	4.26	
72	1	72	201	33654	4.28	
73	1	73	199	33853	4.29	
74	1	74	195	34048	4.30	
75	1	75	194	34242	4.32	
76	1	76	190	34432	4.33	
78	2	78	189	34621	4.36	
79	1	79	184	34805	4.37	
81	2	81	182	34987	4.39	
82	1	82	181	35168	4.41	
83	1	83	180	35348	4.42	
84	1	84	178	35526	4.43	
85	1	85	177	35703	4.44	
86	1	86	169	35872	4.45	
87	1	87	168	36040	4.47	
88	1	88	162	36202	4.48	
89	1	89	158	36360	4.49	
91	2	91	150	36510	4.51	
92	1	92	149	36659	4.52	
94	2	94	148	36807	4.54	
96	2	96	145	36952	4.56	
97	1	97	143	37095	4.58	
99	2	99	141	37236	4.60	
102	3	102	140	37376	4.63	
104	2	104	139	37515	4.64	
105	1	105	137	37652	4.65	

106	1	106	135	37787	4.66	
107	1	107	118	37905	4.67	
108	1	108	110	38015	4.68	
109	1	109	108	38123	4.69	
110	1	110	106	38229	4.70	
111	1	111	104	38333	4.71	
112	1	112	103	38436	4.72	
113	1	113	100	38536	4.73	
114	1	114	99	38635	4.74	
115	1	115	97	38732	4.75	
116	1	116	94	38826	4.75	
119	3	119	93	38919	4.78	
121	2	121	92	39011	4.80	
122	1	122	91	39102	4.80	
123	1	123	89	39191	4.81	
125	2	125	88	39279	4.83	
126	1	126	87	39366	4.84	
128	2	128	86	39452	4.85	
129	1	129	85	39537	4.86	
130	1	130	83	39620	4.87	
131	1	131	82	39702	4.88	
134	3	134	81	39783	4.90	
137	3	137	80	39863	4.92	
140	3	140	79	39942	4.94	
144	4	144	78	40020	4.97	
146	2	146	77	40097	4.98	
147	1	147	76	40173	4.99	
149	2	149	75	40248	5.00	
150	1	150	74	40322	5.01	
154	4	154	73	40395	5.04	
156	2	156	72	40467	5.05	
157	1	157	71	40538	5.06	
161	4	161	82	40620	5.08	
162	1	162	81	40701	5.09	
163	1	163	80	40781	5.09	
166	3	166	79	40860	5.11	
167	1	167	78	40938	5.12	
170	3	170	77	41015	5.14	
171	1	171	76	41091	5.14	
173	2	173	75	41166	5.15	
175	2	175	74	41240	5.17	
178	3	178	72	41312	5.18	
182	4	182	47	41359	5.20	
185	3	185	46	41405	5.22	
187	2	187	45	41450	5.23	
190	3	190	44	41494	5.25	
192	2	192	43	41537	5.26	

196	4	196	42	41579	5.28	
198	2	198	41	41620	5.29	
202	4	202	40	41660	5.31	
206	4	206	39	41699	5.33	
208	2	208	38	41737	5.34	
211	3	211	37	41774	5.35	
213	2	213	36	41810	5.36	
218	5	218	35	41845	5.39	
222	4	222	34	41879	5.40	
225	3	225	33	41912	5.42	
230	5	230	32	41944	5.44	
234	4	234	31	41975	5.46	
239	5	239	30	42005	5.48	
242	3	242	29	42034	5.49	
249	7	249	28	42062	5.52	
255	6	255	27	42089	5.54	
261	6	261	26	42115	5.57	
263	2	263	25	42140	5.57	
268	5	268	24	42164	5.59	
274	6	274	23	42187	5.61	
282	8	282	22	42209	5.64	
286	4	286	21	42230	5.66	
294	8	294	20	42250	5.68	
305	11	305	18	42268	5.72	
311	6	311	17	42285	5.74	
321	10	321	16	42301	5.77	
334	13	334	15	42316	5.81	
352	18	352	14	42330	5.86	
359	7	359	13	42343	5.88	
374	15	374	12	42355	5.92	
395	21	395	11	42366	5.98	
418	23	418	9	42375	6.04	
465	**47**	**465**	**8**	**42383**	**6.14**	

Table 3 Scatter of Journals and articles over Bradford's zone

Zone	No. of journals	% of Journals	No. of articles	% of articles	Bradford Multiplier
1	14	3.01	14,236	33.59	-
2	31	6.7	13,850	32.68	2.21
3	420	90.32	14,297	33.73	13.54
All zones	465	100	42,383	100.00	7.87*

* Mean value of the Bradford Multiplier

Therefore, Leimkuhler model is applied for studying the applicability of Bradford's law

8.2.2 Application of Leimkuhler model

For testing the Bradford's law, the 465 journals are divided in to three zones, since Bradford assumes that there should be minimum three zones i.e. p=3, then the value of k can be calculated using the formula (4)

$\boldsymbol{k}= (1.781 * Ym)^{1/p} = (1.781 * 1939)^{1/3} = \mathbf{14.71}$

$\boldsymbol{Y_0} = A/P = 42383/ 3 = \mathbf{14128}$

$\boldsymbol{r_o}= T(k\text{-}1)/ (k^p\text{-}1) = 465\ (14.71 - 1)/ (14.71^3\text{- } 1)= \mathbf{2}$

$\mathbf{r_1}=r_0*k = 2*14.71 =\mathbf{29.42}$

$\mathbf{r_2} = r_0*k^2 = 2*(14.71)^2 = \mathbf{432.76}$

$\boldsymbol{a}= Y_0 / \log k = 14128/ 1.16 = \mathbf{12179.3}$

$\boldsymbol{b} = k\text{-}\ 1/ r_o = 14.71\text{-}1/ 2 = \mathbf{6.85}$

The findings of calculation are shown in Table 4

From table 4, the number of journals in nucleus is found to be 2 and k= 14.71 is a multiplier. Therefore, the Bradford distribution is

$$2: 2*14.71: 2*14.71^2 \approx 1: n: n^2$$

$$2: 29.42: 432.76 = 464.18$$

Percentage of error = $\frac{464.18-465}{465} X\ 100$ = 0.1763%

The Percentage of error of the distribution is 0.17% and it is also observed that, the number of journals contributing the articles to each zone increases by a multiplier of 14.71. Specifically, the first zone, containing 2 journals contributes 2,925 articles, the second zone consisting 30 journals produces 17,505 articles, and the third zone accounting for 433 journals provides 15, 289 articles.

Table 4 Bradford's zones of scattering

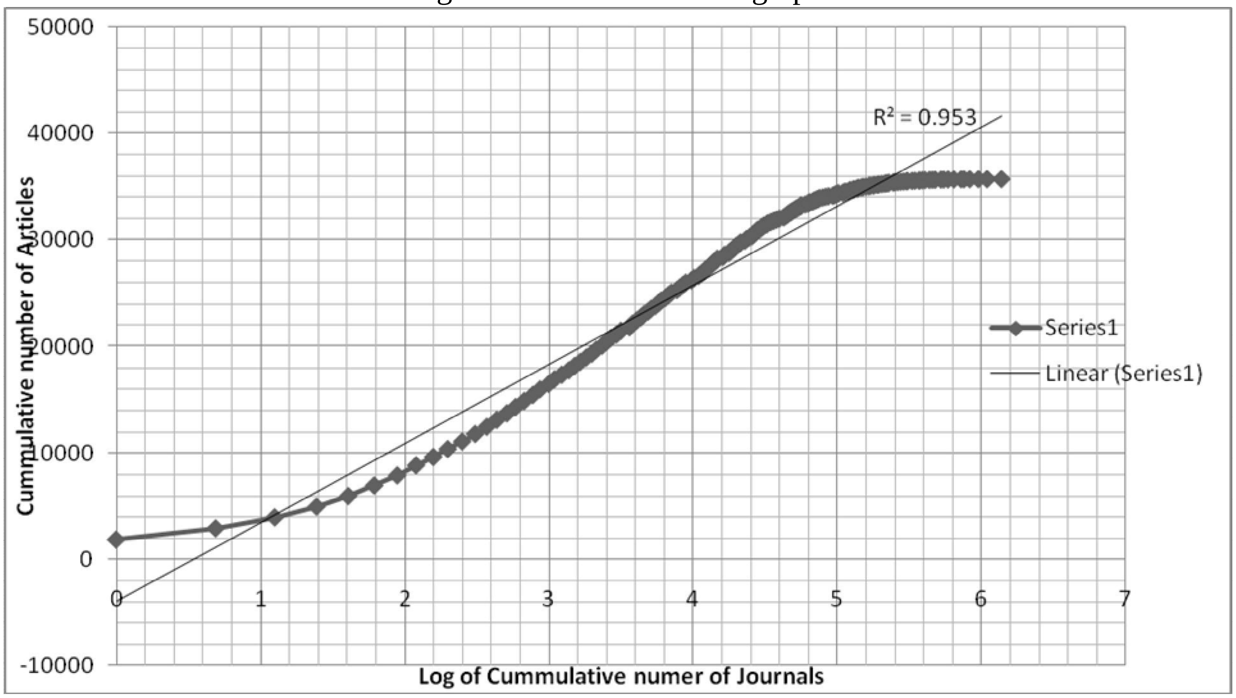
Zone	No. of journals	% of Journals	No. of articles	% of articles	Bradford Multiplier
1	2	0.44	2925	8.19	-
2	30	6.45	17505	49.11	15
3	433	93.11	15289	42.80	14.43
All zones	465	100	35719	100	14.71

The Bradford's algebraic interpretation of the law, $1{:}n{:}n^2$ is followed in this case. But the number of articles in each zone does not follow one third of the total citations.

8.3 Graphical Formulation

The graphical (formulation) approach was developed by Brookes, which tries to verify the Verbal formulation of Bradford's Law (Brookes, 1969). The graph in the figure 1 is logarithmic plot of the cumulative number of journals on the horizontal (x) axis and cumulative number of articles on the vertical (y) axis. If the distribution confirms the Bradford's law it will display three characters (i) a rapid rise for the first few points (ii) a major portion of linear relation between two variables and (iii) a 'droop' at the tail end of the distribution indicating the incompleteness of the bibliography.

Figure 1 Bradford's Bibliograph



The figure 1 shows the typical Bradford's curve with a Groos droop, where the journals are plotted against their productivity.

Conclusion

Bibliometric studies have been very useful in determining various scientific indicators,evaluation of scientific/research output, and selection of journals for libraries and in understanding growth and development of a research field. Libraries have the responsibility of selecting and procuring the best literature in the form of bookstand journals in a given field of research. As cost of books and subscription amount of journals is increasing at a rapid pace, it is increasingly important for libraries to carefully select the resources. Bradford's Law of Scattering is one such bibliometric law, which is helpful in selecting core journals in a research field. In this study an attempt is made to apply Bradford's Law of Scattering to the journal articles literature of Materials Science for the period 1995-2014. Search in Web of Science Core Collection database retrieved 42,383articles published in 465 journals.

The journal distribution pattern of the Material Science literature in India does not confirm the Bradford's distribution pattern, i.e., 1: n; n^2 and it may due to incomplete bibliography or interdisciplinary nature of articles. When the multiplier for the first two zones were calculated, the Bradford's law could be modified as 1: n: $4n^2$ (where n =14) and this modification fits the Bradford Law for the data set. But when the mean value of multiplier is considered (7.87), this modified Bradford law does not fit the journal distribution, as the percentage of error is very high

(113.18 per cent). When the Leimkuhler model is employed for the verification of Bradford's law, it is found that the law find valid for the data set. The percentage of error is found to be the most negligible (0.17 per cent). Bradford's Law of Scattering is an area where much work has been done. But the number of articles in each zone does not follow the one third of the total articles. However, till now, no one has come out with a single model that fits fairly well to most of the data set.

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