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Impact of Bradford's Law of Scattering on Drone Technology Publications

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ABSTRACT

The present study has made an attempt to test one of the most important law in Bibliometric studies i.e. Bradford's Law of Scattering. It describes the quantitative relation between journals and articles. In this study, a total of 3433 articles were retrieved from Web of Science database during the span of 2008-2017, covered in the field of Drone Technology. Data analysed with respect to relative growth rate and doubling time of literature. It is calculated and scattered all 3433 articles in 1155 journals. It reveals that Journal of Intelligent & Robotic System secured top position with the highest number of publications 140 (4.08%), followed by Remote Sensing with a share of 127 (3.70%) and Sensors occupied the third position with 101 (2.94%) publications. Top ten ranked journals have 682 (19.86%) publications out of 3433 publications of total output. The journal distribution as per Bradford's law reveals the ration as 32:195:928 in drone technology, dispersion of journal titles in drone technology does not satisfy Bradford's law of Scattering in theoretical aspect. But tested through Leimkuhler model, it is found fit the data for the Bradford Multiplier (k) at 3.85.

Keywords: *Bradford's Law of Scattering; Drone Technology; Bibliometric Study; Productivity of Journals; Relative Growth Rate; Doubling Time.*

INTRODUCTION

Due to speedy growth and advancement of Artificial Intelligence, the enormous changes have been seen in every sector over the world. As the technology becomes more and more advanced and casts fall, machine-oriented things are developing rapidly. However, a rising works among the scientists and researchers is whether machines will one day become mankind's worst threat. The efforts of scientists and researcher now invented driverless cars, flying taxies, automated super market, drones, and so on. In these innovations, drone technology is one ofthe widely using for various purposes.

Drones are formally known as Unmanned Aerial Vehicles (UAVs) are automated remotely piloted vehicles; these can fly for long periods of time at a controlled level of speed and height. In the 20th Century, military research precipitated many widely used technological innovation and drones are one of them, which used for reconnaissance, Airstrikes surveillance, and targeted attacks. Drones, flying robots extend their services to the field of Filming and Journalism, Shipping and Delivery, Disaster Management, Rescue Operations and Health Care, Archaeological Survey, Geographic Mapping, Law enforcement, Safety Inspections, Agriculture, Wildlife Monitoring, Weather forecasting, etc. these are the practical and essential application of drones. In addition to, drones can be used for taking an effective selfies, which are became the *'word of the decade'* and also popular for drone racing[1]

BRADFORD’S LAW OF SCATTERING

Journals plays vital role in the scientific communication. They appear periodically and focussed topically, they have established standards of quality control and often they are involved in the academic gratification system.Modelling science or understanding the functioning of science has a lot to do with journals and journal publication characteristics. Journal publication characteristics are point where Bradford law can contribute to the larger topic of science models[3]

In 1934, S.C. Bradford has been carried out the Bradford Law of Scattering based on literature observation. In his first paper entitled ‘Source of Information on specific subjects’ observed and examined two bibliographies on Applied Geophysics (1928-1931) and Lubrications (1932-1937) at Science Library, Britain. Bradford prepared list of journals in descending order of source, based items contributed for journals. He describes that, “the whole range of periodicals thus acts as a family of successive generation of diminishing kinship, each generation being greater in number than the preceding, and each constituent of a generation inversely according to its degree of remoteness [2]

Bradford discovered that, when equally dividing all articles in specific subject in to three groups or zones, the articles for the first zone would come from a small ‘core’ group of journals. The second would require more journals to achieve the same number of articles, and third zone exponentially requires more than second zone. In moving from zone one to zone three there is a ‘diminishing productivity’ described by Bradford, which has become popular as Bradford’s Law of Scattering.

Bradford’s verbal formulation stated that, *‘If scientific journals are arranged in order of decreasing productivity of articles on a given subject, they may be divided into a nucleus of periodicals more popularly 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’*

REVIEW OF RELATED WORKS

Mayr[4] evaluated the effectiveness of the bibliometric technique Bradfordizing in an information retrieval scenario. Bradford's Law used to re-rank topical document and tested 164 standardized Information retrieval topics and intellectual assessments. Banateppanavar and Dharanikumar[5]investigated the performance of LIS Professionals in research output published in the Journal of Library Management (e-Journal) between the span of 2010-2012. A total of 139 articles with 3053 citations were found and used authorship pattern, subject-wise distribution, references per article, and adopted Bradford's Law of Scattering to analyze the data. Zafrunnisha[6] analysed 100 PhD theses accepted in the field of Psychology at Jawaharlal Nehru Technological University, Anantapur to identify the Bradford's zones and productivity of journals cited in the theses. As per the Bradford's Law Scattering, the ratio of journals distribution is 17:46:358 in field of psychology. Venable and et.al[7] identified and analysed top 100 journals ranked by h-index for Neurosurgery and its subspecialties between year 2009 to 2013. This study used Bradford's verbal law with 4 zone models and articles were distributed in 8:39:211:7200 journals respectively in 1, 2, 3 and 4 zones. The study carried out by Viju[8] on the data of journals cited by PhD Research Scholar at Universities of

Maharashtra state for their Doctoral research. This study 138 theses taken in to account which contained 5467 references, covered in 798 periodicals. By rank list, Annals of Library Science and Documentation placed in top position with 207 citations followed by College and Research Libraries with 184, and Herald of Library Science with 160 citations were the most preferred journals. Scattering of Journals over the Bradford's zones 13:96:689 and 1712:2338:1417 citations scattered in this study. Tripathi and Sen[9] tested Bradford's Law on Crop Science literature, and comprised 10,100 articles pertained to 738 journals indexed in Indian Science Abstract and CAB Abstract during the span 1965 to 2010. It seems that Bradford's multiplier in the second zone is 4.50 and third zone 12.45, Journals distributed in Bradford's zones is 12:54:672 and articles scattered in 3309:3434:3357 respectively core zone, zone 2, and zone 3. Singh and Bebi[10] identified the core journals in the field of social science based on social science theses. This study fit into the Bradford's law.

OBJECTIVES OF THE STUDY

The main aim of the present study is to analyse the global scientific research performance of *'Drone Technology'* for the ten years between 2008-2017.

1. To study the research output on 'Drone Technology' and its growth using Relative Growth Rate(RGR), Doubling Time(DT), and Annual Growth Rate (AGR);
2. To rank the core journals in the field of Drone Technology; and
3. To test Bradford's law of scattering based on Leimkuhler model & Egghe's formulation.

METHODOLOGY

The relevant article for this study was collected using Web of Science an international online database which published by Thomson Reuters. A total of 3433 journal articles were found covered in 1155 journals on drone technology during the period of 2008-2017. This study have been tested Bradford's Law of Scattering through Leimkuhler model and Egghe's formulation.

RELATIVE GROWTH RATE (RGR) & DOUBLING TIME (DT)

The primary parameters of the Scientometrics are Relative Growth Rate (RGR) and Doubling Time (DT). This study calculates the global research growth with year-wise journal articles produced on 'Drone Technology' obtained from Web of Science dataset between the span of 2008-2017. RGR indicates the escalation in number of article per unit of a time. It means Relative Growth Rate (RGR) over the specific period of interval can be represented as;

Relative Growth Rate (RGR)

$$\mathbf{1\text{-}2^R = \frac{\log_e G_2 - \log_e G_1}{t_2 - t_1}}$$

Whereas, the above equation denoted that, $1\text{-}2^R$ (aa^{-1} $year^{-1}$), means relative growth rate over the specific period of interval; aa^{-1} = average number of articles; $\log_e G_1$ = logarithm of beginning number of articles; $\log_e G_2$ = logarithm of ending number of articles after a specific span of interval. t_1& t_2 indicates initial time and ending time respectively. Relative Growth Rate can be calculated by following procedure:

$$2009=\frac{\log_e(198)-\log_e(86)}{2009-2008}$$

$$=\frac{5.288-4.454}{1}=\frac{0.834}{1}$$

= 0.834

$$2010=\frac{\log_e(321)-\log_e(198)}{2010-2009}$$

$$=\frac{5.771-5.288}{1}=\frac{0.483}{1}$$

= 0.483

In the same way, Relative Growth Rate calculated for other years.

As indicated in Table 1 Relative Growth Rate has been gradually decreased during between the year 2009 (0.834) to 0.306 (2014) and bit by bit increased from the year 2015 (0.324) to 2017 (0.361). The growth of literature preferable described by Cumulative number of total and it can be defined merely by summing up the yearly publications and it integration of the function of the yearly publications.

Table 1. Relative Growth Rate (RGR) & Doubling Time (DT)

Year	No. of Publications	Cumulative Total	G_1	G_2	RGR	Mean RGR	DT	Mean DT
2008	86	86	-	4.454				
2009	112	198	4.454	5.288	0.834		0.831	
2010	123	321	4.718	5.771	0.483		1.434	
2011	157	478	4.812	6.170	0.398		1.740	
2012	187	665	5.056	6.500	0.330	**0.511**	2.099	**1.526**
2013	248	913	5.231	6.817	0.317		2.186	
2014	327	1240	5.513	7.123	0.306		2.264	
2015	474	1714	5.790	7.447	0.324		2.141	
2016	6790	2393	6.161	7.780	0.334		2.077	
2017	1040	3433	6.521	8.141	0.361	**0.328**	1.920	**2.118**
Total	**3433**							

Doubling Time (DT)

Doubling time refers to time required for publications/articles/citations to become double of existing number of Relative Growth Rate (RGR). Generally, the number of years in which publications twice in its size and it can be approximated using growth rate. If the number of publications/ articles/citations of the particular area of subject twice over a given period, then the difference between the logarithms of numbers at the beginning and end of this period must be the logarithm of number 2. If natural logarithm is used this difference has a value of 0.693(Mahapatra, 1985). Therefore, the corresponding doubling time for each definite period of interval and publications can be calculated by the following equation.

$$\textbf{Doubling Time(DT)}=\frac{\log(2)}{\log(1+r)}=\frac{0.693}{R}$$

Therefore,

Doubling time for article:

$$DT(a)=\frac{0.693}{R}$$

$$=\frac{0.693}{1\text{-}2^{R}\,(aa^{-1}\ year^{-1})}$$

$$2009=\frac{0.693}{0.834}=\mathbf{0.831}$$

$$2009=\frac{0.693}{0.483}=\mathbf{1.434}$$

In the same way, doubling time has been calculated for remaining years.

Growth Rate and Doubling Time for research output has been calculated and presented in Table 2 and figure 2. Doubling time has been slowly increased during the specific period. Doubling time increased during the span of 2009 (0.831) to 2014 (2.264), and it suddenly decreased in the year 2015 (2.141) to 2017 (1.920). Therefore, doubling time increasing but it is not showing exponential growth rate. The mean value for the first five years i.e. 2008-2012 is 1.526 and further five years, 2.118 is the mean for years 2013-2017.

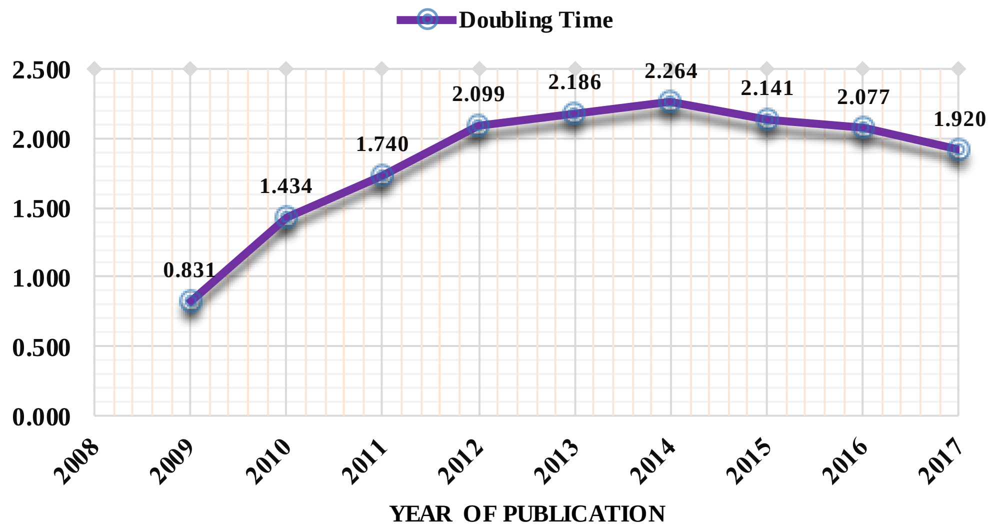

Fig. 1 Doubling time for research output

PRODUCTIVITY OF JOURNALS

The scientific journals play vital role in communication of scientific field. To determine most productivity journals in the study field, preferred sources are identified by the researcher for their publications. The most productivity journals presented in the Table 2. Top 30 ranked source titles listed and indicated up to 35 ranked journals merged by respective numbers of articles in Table2. It reveals that Journal of Intelligent & Robotic System secured top position with highest number of publications 140 (4.08%). It is followed by Remote Sensing with a share of 127 (3.70%) and Sensors occupied third position with 101 (2.94%) publications. Totally, top ten ranked journals have 682 (19.86%) publications out of 3433 publications of total output.

Table 2. Rank list of Journals covered Drone Technology literature, during 2008-2017

Sl. No.	Rank	Source Title	No. of Articles covered	Percentage (%)
1	**1**	Journal Of Intelligent & Robotic Systems	140	4.08
2	**2**	Remote Sensing	127	3.70
3	**3**	Sensors	101	2.94
4	**4**	Proceedings Of The Institution Of Mechanical Engineers Part G-Journal Of Aerospace Engineering	68	1.98
5	**5**	International Journal Of Remote Sensing	51	1.49
6	**6**	Journal Of Aircraft	48	1.40
7	**7**	Journal Of Guidance Control And Dynamics	43	1.25
8	**8**	Apidologie	36	1.05
9	**9**	Aerospace Science And Technology	35	1.02
10	**10**	International Journal Of Advanced Robotic Systems	33	0.96
11	11	IEEE Transactions On Geoscience And Remote Sensing	32	0.93
12	11	IEEE Transactions On Aerospace And Electronic Systems	32	0.93
13	12	PLOS One	28	0.82
14	13	Journal Of Aerospace Engineering	27	0.79
15	14	Journal Of Applied Remote Sensing	24	0.70
16	14	Aircraft Engineering And Aerospace Technology	24	0.70
17	15	IEEE Transactions On Control Systems Technology	23	0.67
18	16	Remote Sensing Of Environment	22	0.64
19	17	Journal Of Field Robotics	20	0.58
20	18	ISPRS Journal Of Photogrammetry And Remote Sensing	19	0.55
21	18	ISA Transactions	19	0.55
22	18	International Journal Of Aeronautical And Space Sciences	19	0.55
23	18	IEEE Geoscience And Remote Sensing Letters	19	0.55
24	19	Precision Agriculture	18	0.52
25	19	International Journal Of Control Automation And Systems	18	0.52
26	20	IEEE-ASME Transactions On Mechatronics	17	0.50
27	20	Chinese Journal Of Aeronautics	17	0.50

28	20	Advanced Robotics	17	0.50
29	21	IEEE Access	16	0.47
30	21	International Journal Of Micro Air Vehicles	16	0.47
31	21	Computers And Electronics In Agriculture	16	0.47
32	22	Journal Of Apicultural Science	15	0.44
33	22	Journal Of Apicultural Research	15	0.44
34	22	International Journal Of Agricultural And Biological Engineering	15	0.44
35	22	IEEE Transactions On Industrial Electronics	15	0.44
36	22	Control Engineering Practice	15	0.44
37	23	Unmanned Systems	13	0.38
38	23	International Journal Of Applied Earth Observation And Geoinformation	13	0.38
39	23	Geomorphology	13	0.38
40	23	IET Control Theory And Applications	13	0.38
41	23	IEEE Journal Of Selected Topics In Applied Earth Observations And Remote Sensing	13	0.38
42	23	Autonomous Robots	13	0.38
43	24	Journal Teknologi	12	0.35
44	24	Mechatronics	12	0.35
45	24	International Journal Of Aerospace Engineering	12	0.35
46	24	IEEE Transactions On Robotics	12	0.35
47	24	Aerospace	12	0.35
48	24	Biosystems Engineering	12	0.35
49	25	Robotics And Autonomous Systems	11	0.32
50	25	Scientific Reports	11	0.32
51	25	Transactions Of The Institute Of Measurement And Control	11	0.32
52	25	Mathematical Problems In Engineering	11	0.32
53	25	Journal Of The Korean Society For Aeronautical And Space Sciences	11	0.32
54	25	ISPRS International Journal Of Geo-Information	11	0.32
55	25	Journal Of Aerospace Information Systems	11	0.32
56	25	Aeronautical Journal	11	0.32
57	25	Earth Surface Processes And Landforms	11	0.32
58	25	Asian Journal Of Control	11	0.32
59	26	Journal Of Economic Entomology	10	0.29
60	26	International Journal Of Hydrogen Energy	10	0.29
61	26	Expert Systems With Applications	10	0.29
62	26	International Journal Of Distributed Sensor Networks	10	0.29
63	26	Defence Science Journal	10	0.29
64	27	Journal Of Systems Engineering And Electronics	9	0.26
65	27	Korean Journal Of Remote Sensing	9	0.26
66	27	IEEE Sensors Journal	9	0.26
67	27	Forests	9	0.26

68	27	IEEE Transactions On Intelligent Transportation Systems	9	0.26
69	27	IEEE Antennas And Wireless Propagation Letters	9	0.26
70	27	AIAA Journal	9	0.26
71	28	Water	8	0.23
72	28	Journal Of Atmospheric And Oceanic Technology	8	0.23
73	28	Journal Of Aerospace Computing Information And Communication	8	0.23
74	28	Geomatics Natural Hazards & Risk	8	0.23
75	28	IEEE Latin America Transactions	8	0.23
76	29	Photogrammetrie Fernerkundung Geoinformation	7	0.20
77	29	Neurocomputing	7	0.20
78	29	Photogrammetric Engineering And Remote Sensing	7	0.20
79	29	Science China-Information Sciences	7	0.20
80	29	Photogrammetric Record	7	0.20
81	29	Security Dialogue	7	0.20
82	29	Optik	7	0.20
83	29	Transactions Of The Japan Society For Aeronautical And Space Sciences	7	0.20
84	29	Journal Of Central South University	7	0.20
85	29	Journal Of Intelligent Material Systems And Structures	7	0.20
86	29	Measurement	7	0.20
87	29	International Journal Of Control	7	0.20
88	29	Insectes Sociaux	7	0.20
89	29	IEEE Aerospace And Electronic Systems Magazine	7	0.20
90	29	European Journal Of Remote Sensing	7	0.20
91	29	Boundary-Layer Meteorology	7	0.20
92	29	Automation In Construction	7	0.20
93	29	Advances In Mechanical Engineering	7	0.20
94	30	Nonlinear Dynamics	6	0.17
95	30	Science China-Technological Sciences	6	0.17
96	30	Journal Of Dynamic Systems Measurement And Control-Transactions Of The ASME	6	0.17
97	30	Journal Of Experimental Biology	6	0.17
98	30	Houille Blanche-Revue Internationale De L Eau	6	0.17
99	30	Frontiers In Plant Science	6	0.17
100	30	IEEE Transactions On Instrumentation And Measurement	6	0.17
101	30	IEEE Communications Letters	6	0.17
102	30	Human Factors	6	0.17
103	30	IEEE Transactions On Vehicular Technology	6	0.17
104	30	Industrial Robot-An International Journal	6	0.17
105	30	IEEE Transactions on Systems Man Cybernetics-Systems	6	0.17
106	30	Electronics Letters	6	0.17
107	30	Biogeosciences	6	0.17

108	30	Applied Sciences-Basel	6	0.17
109	30	Cryosphere	6	0.17
110	31	28 Journals with 5Articles each	140	4.08
111	32	41 Journals with 4 Articles each	164	4.78
112	33	76 Journals with 3 Articles each	228	6.64
113	34	165 Journals with 2 Articles each	330	9.61
114	35	736 Journals with 1 Articles each	736	21.44
Total		**1155 Journals**	**3433**	**100**

PRACTICAL ASPECT OF BRADFORD'S LAW OF SCATERING

It is apparent Table 3, it was observed that, core 32 journals covered 1140 articles, in second zone 195 journals covered 1146 article and third zone 928 journals covered 1147 articles. According to Bradford's Law, the zones, thus identifies will form an approximately geometric series in the form ***1:n:n²***. *Whereas, Bradford's Multiplier mean is ~5.426.* It was found that the relationship of each zone in the present study is 32:195:928. It does not fits to the Bradford's law of Scattering.

Table 3: Zone-wise distribution of Journals

Zones	No. of Journals	No. of Articles	Percent of Articles (%)	k(Bradford's Multiplier)
1	32	1140	33.21	-
2	195	1146	33.38	6.094
3	928	1147	33.41	4.76
	1155	**3433**	**100.00**	**Mean ~ 5.426**

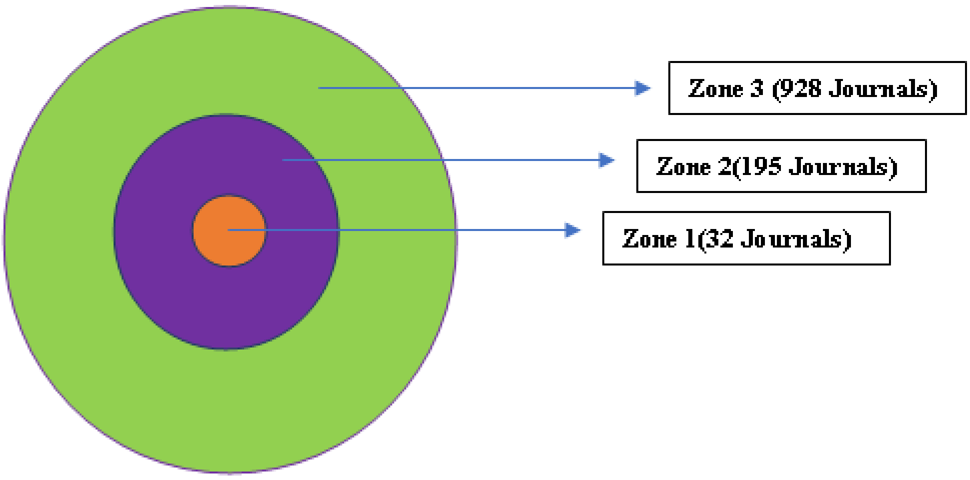

Fig.2 shows Distribution of Bradford's Law of Scattering

Leimkuhler Model

Bradford's Law describes a quantitative relationship between journals and papers. Many authors have developed and formulated different models to evaluated Bradford's law of scattering. Leimkuhler (1967)developed a model based on Bradford's verbal formulation as;

R (r)= a log(1+br) - (1)

Egghe explained and considered Leimkuhler law as;

R (r)=Y_0 and 1+br=k

Using above values equation 1 would be:

Y_0= a log k - (2)

Thus **a = Y_0/log k - (3)**

And b= (k-1)/r_0- (4)

$r_0$is the number of Journals/ sources in the first Bradford's group, **Y_0** is the number of items in every Bradford group (all these groups of items being of equal sizes) and **k** is the Bradford's multiplier.

R(r) is the cumulative number items produced by the sources of rank 1,2,3…**r**, and **a** and **b** are constants appearing in the law of Leimkuhler. In forming Bradford's groups, it is shown that the number of groups **p** is a parameter that can be chosen freely.

Egghe's Mathematical Formula

Egghe (1986)has given a mathematical formula for calculating the Bradford multiplier as:

$k= (e^{\gamma} \times Ym)^{1/p}$ - (5)

k=Bradford's multiplier

e =2.718 (Constant Value)

γ = 0.5772 (Euler's Number)

Ym = Number of articles in the most productivity Journals (3433)

P=3 Zones

Where $e^{\gamma}$is the Euler's number (value 1.781)

e^{γ}=2.718^0.5772 = 1.781

k= $(1.781\times32)^{1/3}$

= $(56.992)^{0.333333}$

k = 3.848321

$$\mathbf{r_0 = \frac{T(k-1)}{k^p-1}} \text{ -(6)}$$

T = Total number of journals under the study

r_0=Number of journals in Bradford's first zone

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

$$r_0 = \frac{1155\ (3.85-1)}{3.85^3-1}$$

$$r_0 = \frac{1155\ (2.85)}{57.0663-1}$$

$$r_0 = \frac{1155\ (2.85)}{56.0663}$$

$$r_0 = \frac{3291.75}{56.06663}$$

$\mathbf{r_0}$=**58.7114**

Different Bradford's zones had been obtained using the value of 'k' and r_0:

Nuclear zone – $r_0 = r_0 \times 1 =$ **58.7114**

First Zone – $r_1 = r_0 \times k = 58.7114 \times 3.85 =$ **226.0389**

Second Zone – $r_2 = r_0 \times k^2 = 58.7114 \times 3.85^2$

$= 58.7114 \times 14.8225 =$ **870.2497**

Hence, Bradford's distribution = 58.7114+226.0389+870.2497=**1155**

Therefore, Bradford's distribution is written as below:

Table 4: Scattering of journals and articles over the Bradford's zones

Zones	No. of journals	No. of articles	Percent of articles
1	58.7117	1140	33.21
2	226.0389	1146	33.38
3	870.2497	1147	33.41

	1155	**3433**	**100.00**

Hence, $58.7114{:}58.7114\times3.85{:}58.71\times(3.85)^2$

$58.7114{:}226.0389{:}870.2497=\mathbf{1155}$

Percentage of error$=\frac{1155\text{-}1155}{1155}\times100=\mathbf{0\%}$

Therefore, it is clearly calculated and noted that, the percentage of error is 0 and Bradford's law of scattering fits very well in the present data set for 3.85.

CONCLUSION

Bradford's Law is one most useful law in Bibliometric studies which is helpful to identify the core journals in a specific field of study. The study presented and made an attempt to apply Bradford's law of scattering to the journals articles of drone technology literature during the span of 2008-2017. According to Bradford's law of Scattering, the articles in each zone should be equal, but in present study does not hold equal number of article in each zone i.e. 32:195:928. Hence, Bradford's Law is calculated and proved through the Leimkuhler and Egghe's model. This study will be useful for the Students, Researcher and Professionals of Science and Technology field and to the libraries it helps in subscription of core journals in the field of Drone technology & Science and Technology.

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