

# Application of Bradford's Law to Artificial Intelligence Research in Indian Medical Healthcare

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**Abstract-** This research focuses on determining the applicability of Bradford's Law of Scattering within the corpus of Indian medical research on Artificial Intelligence (AI) in healthcare. The study analyzing 9,774 papers that amassed 123,043 citations, the data was retrieved from the Web of Science citation database covering the period from 2005 to 2024. The study examined annual research output trends, researcher communication preferences, and the productivity of journals. The results show that year 2023 recorded the highest volume of publications, totaling 2104 (21.53%). The year 2021 demonstrated the peak research influence, as measured by total citations 26356 (21.42%) and an h-index of 69. Furthermore, journal impact was not solely linked to publication volume. Despite publishing fewer papers than volume leaders, the highly specialized "Expert Systems with Applications" demonstrated superior quality, achieving the highest Average Citations per Paper (ACPP) of 36.03. The Bradford's analysis strongly confirmed the law's applicability, with the core zone consisting of 1.90% of journals contributing 33.22% of the literature. This clear stratification, supported by a negligible negative error (0.49%), confirms the concentration of key AI medical literature in a small core of highly productive journals.

**Keywords:** Artificial Intelligence (AI), Machine Learning, Health Care, Diagnosis, Treatment, India, Countries, Scientometric, Bibliometrics, Web of Science (WoS), Bradford's Law, Bradford's Multiplier, Leimkuhler Model.

## I. INTRODUCTION

In the medical healthcare, artificial intelligence is employed for a variety of purposes, such as disease diagnosis, creating individualized treatment regimens, and supporting robotic surgery. With the ultimate goal of supporting healthcare professionals and improving patient care. According to (Haenlein & Kaplan, 2019) Artificial Intelligence is defined as "a system's ability to interpret external data correctly, to learn from such data, and to use those learning's to achieve specific goals and tasks through flexible adaptation and established as an academic discipline in the 1950", (See cited from p.2).

Artificial intelligence applications in healthcare: - Disease diagnosis and detection: Compared to human evaluation alone, AI can identify diseases like cancer and heart issues more quickly and precisely by analyzing medical pictures like X-rays and ECGs. Personalized treatment plans: By identifying the therapies that are most effective for each patient, AI evaluates patient data to suggest individualized treatment plans that improve results and minimize adverse effects. Robotic surgery: AI helps in robotic-assisted surgery, allowing for higher magnification and more accurate movements for intricate procedures.



Figure-1: Artificial Intelligence in medical field

Source:<https://www.news-medical.net/health/Artificial-Intelligence-in-Cardiology.aspx> Bradford's Law can be used to follow the development of research subjects, find the most productive journals, and improve in the field of artificial intelligence in medical literature. The law assists in identifying the most important sources by classifying AI medical journals into three zones (core, allied, and peripheral) according to publication frequency. This helps researchers and librarians assess information flow and manage collections by offering insights into fundamental subject areas and emerging trends.

Scientometrics is used to statistically measure and analyze scientific activity in order to assess the impact and productivity

of research, track research trends, guide science policy, and display scientific knowledge. It evaluates individual academics, organizations, and entire fields using metrics like publications, citations, and patents to inform funding, recruiting, and promotion decisions.

## II. OBJECTIVES OF THE STUDY

- Analyze year - wise growth of papers and citations.
- To analyze the most productive journal in the field of Artificial Intelligence in medical literature in India.
- To test the applicability of Bradford’s Law and Egghe’s methods.

## III. METHODOLOGY

The record from the Clarivate Analytics “Web of Science” (WoS) citation database. Information obtained via an advanced search method by utilizing the term CU= INDIA AND (TS=“Artificial Intelligence” OR TS=“AI” OR TS=“Machine learning”) AND (TS=Health Care OR TS=Healthcare OR TS=Medicine OR TS=Medical\* OR TS=diagnosis OR TS=Treatment\* OR TS=Amelioration OR TS=Cure\* OR TS=Disease\* OR TS=Injury) Indexes=SCI-EXPANDED, SSCI, A&HCI, ESCI Timespan=2005-2024, 2005-01-01 to 2024-12-31 total 20 years. It was downloaded in both plain text and Comma Separated Values (CSV) file formats. The data has been presented for study and discussion using tables and graphs. For analysis, 9,774 records were downloaded in both plain text and Comma Separated Values (CSV) file formats. “HistCite” software and a “Microsoft Excel” spreadsheet were used to examine the data and the data has been presented for study and discussion using tables and graphs.

## III. RESULTS AND DISCUSSION

### 1. Year - wise growth papers and citations

The research field of artificial intelligence (AI) in medical health care in India has demonstrated substantial growth in publication output and impact over the two-decade period from 2005 to 2024.

A total of 9,774 papers were published, accumulating 123,043 citations. The publication trend indicates a significant and accelerating increase, particularly in the later years of the study period. Key highlights include a lowest output of only 8 papers

in 2006 and a peak in publication volume in 2023 with 2,104 papers, representing 21.53% of the total. According to (Hulloli & Venkatesh, 2021) “Research on Psychology subject total 12,543 articles with 96,871 citations have been published during the research from 2001 to 2020” (See cited from p.54). Furthermore, the year 2021 stands out as the most impactful in terms of citation count, achieving the highest total citations and h-index, indicating high-quality and influential research as shown table-1.

Table-1: Year - wise growth papers and citations

Year	Papers	Papers %	Citations	Citations %	H-Index
2005	11	0.11	295	0.24	8
2006	8	0.08	137	0.11	5
2007	12	0.12	238	0.19	5
2008	25	0.26	345	0.28	11
2009	26	0.27	181	0.15	8
2010	25	0.26	742	0.60	13
2011	24	0.25	955	0.78	10
2012	40	0.41	540	0.44	15
2013	78	0.80	2128	1.73	23
2014	79	0.81	918	0.75	18
2015	154	1.58	3235	2.63	32
2016	204	2.09	4238	3.44	36
2017	246	2.52	4169	3.39	33
2018	361	3.69	9444	7.68	50
2019	526	5.38	11961	9.72	54
2020	826	8.45	21408	17.40	72
2021	1309	13.39	26356	21.42	69
2022	1983	20.29	22382	18.19	55
2023	2104	21.53	11228	9.13	38
2024	1733	17.73	2143	1.74	16
<b>Total</b>	<b>9774</b>		<b>123043</b>		<b>118</b>
<b>CAGR</b>	<b>30.51</b>		<b>11.00</b>		
<b>Compound Annual Growth Rate</b>					

The Compound Annual Growth Rate (CAGR) formula used.

$$CAGR = \left( \frac{\text{Ending Value}}{\text{Beginning Value}} \right)^{\left( \frac{1}{\text{Number of Years}} \right)} - 1$$

[[http://en.wikipedia.org/wiki/Compound\\_annual\\_growth\\_rate](http://en.wikipedia.org/wiki/Compound_annual_growth_rate)] is used to calculate the growth rate. (09.09.2013). It provides the average annual growth rate. When comparing the growth rates of various years, the value is suitable. Where the number of years is represented by n. In this instance, n=20. India has a compound annual growth rate of 11.00 citations and 30.51 papers.

The publication trend demonstrates a period of slow initial adoption followed by a surge in research activity, confirming

the slow growth mentioned in the data, which ultimately accelerated. The data confirms a slow-growth pattern from 2005 onwards, which has since rapidly accelerated, especially leading into the latter years of the period. The number of papers increased again in 2024, signaling continued growth in this domain. The concentration of the highest citations (21.42%) in 2021, despite 2023 having the most publications, suggests that the research published in 2021 was exceptionally well-received and highly influential within the academic community.

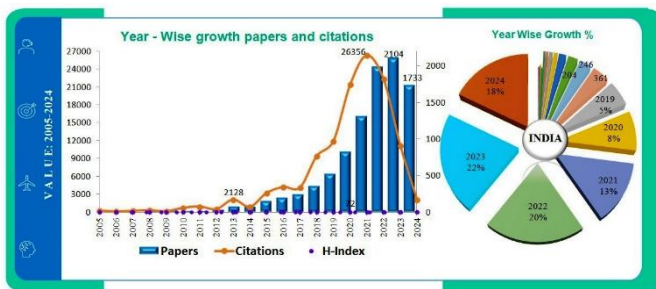


Figure-2: Year - wise growth papers and citations

The field of AI in field of medical research in India has transitioned from a minimal output in the mid-2000s to a highly productive and impactful research area by the 2020s. While 2023 saw the largest volume of papers, 2021 demonstrated the peak research influence as measured by total citations and h-index showing figure-2.

## 2. Most Productive on Artificial Intelligence field of Medical Literature Journals in India

The study investigated the distribution of research articles in the field of Artificial Intelligence (AI) in medical literature by Indian researchers and scientists over a 20-year period. The study applied Bradford's Law of Scattering, a core principle in Scientometrics that describes how articles on a specific subject are scattered across a large number of journals.

The provided data presents an analysis of highly cited papers across several academic journals, focusing on the number of papers, total citations, and the Average Citation per Paper (ACPP). The ACPP is a key indicator of a journal's quality and the relative impact of its published works. The “Multimedia Tools and Applications” this journal ranks first in terms of the number of highly papers 330, representing 3.38% and 2260 (1.84%) of the total citations recorded with its ACPP of 6.85, 2nd ranked “IEEE Access” 290 papers (2.97%), this journal exhibits a significantly higher citation impact, with a total of

5915 (4.81%) citations resulting in a strong ACPP of 20.40 the high ACPP, despite having fewer papers than the first-ranked, is noted as a good indication for quality journals. The “Biomedical Signal Processing and Control” occupying the third rank, this journal has 154 papers (1.58%) and 2003 (1.63%) citations and its ACPP is 13.01, which is higher than the first-ranked journal but lower than the second. Ninth ranked journal title “Computers in Biology and Medicine” 88 (0.99%) papers, 2452 (1.99%) citations with 27.86 ACPP received.

Observed high Impact Specialization journal title “Expert Systems with Applications” ranked fourteenth, this journal demonstrates the maximum ACPP of 36.03 and this high average is achieved with a relatively small number of 71 (0.73%) papers and 2558 (2.08%) citations published here, signaling significant influence in its specific field. The top six ranked journals collectively contribute to nearly 11% of the total highly cited papers published and the remaining 9,768 journals contributed below 1% of the papers, highlighting the concentration of high-impact research within a small number of leading journals.

### A) Bradford's Law Multiplier (k):

Table-2: Ranked List of Artificial Intelligence Journals Publications in India

SL. No	Name of the Journal	TP	TP%	TC	TC%	ACPP
1	Multimedia Tools and Applications	330	3.38	2260	1.84	6.85
2	IEEE Access	290	2.97	5915	4.81	20.40
3	Biomedical Signal Processing and Control	154	1.58	2003	1.63	13.01
4	Diagnostics	116	1.19	1231	1.00	10.61
5	Scientific Reports	104	1.06	1250	1.02	12.02
6	Journal of Intelligent & Fuzzy Systems	103	1.05	181	0.15	1.76
7	Materials Today-Proceedings	96	0.98	719	0.58	7.49
8	Soft Computing	91	0.93	772	0.63	8.48
9	Computers in Biology and Medicine	88	0.90	2452	1.99	27.86
10	Neural Computing & Applications	85	0.87	1625	1.32	19.12
11	Expert Systems	78	0.80	603	0.49	7.73
12	Archives of Computational Methods in Engineering	76	0.78	1029	0.84	13.54
13	Wireless Personal Communications	75	0.77	556	0.45	7.41
14	Expert Systems with Applications	71	0.73	2558	2.08	36.03
15	CMC-Computers Materials & Continua	68	0.70	551	0.45	8.10
16	Journal of Ambient Intelligence and Humanized Computing	61	0.62	1195	0.97	19.59
17	Computational Intelligence and Neuroscience	58	0.59	510	0.41	8.79
18	Sensors	56	0.57	1162	0.94	20.75
19	Electronics	55	0.56	1118	0.91	20.33
20	IEEE Sensors Journal	48	0.49	728	0.59	15.17
21	60 Journals (Publication within the range of 46-16)	1688	17.27	23804	19.35	14.10
22	2663 Journals (Publication within the range of 15-1)	5983	61.21	70821	57.56	11.84
<b>Total</b>		<b>9774</b>	<b>100</b>	<b>123043</b>	<b>100</b>	<b>12.59</b>

TP-Total Papers, TP%-Total Papers Percentage, TC-Total Citation, TC%-Total Citation Percentage, ACPP- Average Citation Per Paper.

The Bradford's Law multiplier (k) was calculated to determine the geometric progression in the number of journals required to produce an equal number of articles in successive zones.

$$k = \frac{\text{Number of Journals in Zone 2}}{\text{Number of Journals in Zone 1}} = \frac{\text{Number of Journals in Zone 3}}{\text{Number of Journals in Zone 2}}$$

**According to (Bradford, 1934) Calculation Formula:** The multiplier (k) is calculated by separating (dividing) the quantity of journals in a zone by the number of journals in the immediately preceding zone.

**Expected Distribution:** According to the theoretical formulation of Bradford's Law, the ratio of journals in the zones should approximate 1 : k : k<sup>2</sup>. (See cited from p-86).

**Zoning Methodology:** The total body of journals was divided into three successive zones (Zone 1, Zone 2, and Zone 3). The primary goal was to distribute the total number of articles (9,774) so that each zone contained almost one-third of the total articles (approximately 9774/3=approx 3258 articles) to minimize the percentage of error. Zone 1 (the Core/Nuclear Zone) contains the fewest journals but the most productive ones, followed by Zone 2 and then Zone 3 (the Peripheral Zone), which contains the largest number of journals with the lowest productivity for the subject.

Table-3: Bradford Zone Journals and Articles

Zone	Journals	Articles	Bradford Multiplier
1	52 (1.90%)	3247 (33.22%)	-
2	413 (15.06%)	3259 (33.34%)	7.94
3	2278 (83.05%)	3268 (33.44%)	5.52
<b>Total</b>	<b>2743</b>	<b>9774</b>	<b>13.46</b>

Bradford's Law suggests that if journals are arranged in order of decreasing productivity on a given topic, they can be divided into three zones (or regions), each producing approximately the same number of articles. The number of journals required to form these zones follows a geometric progression with the ratio 1 : n : n<sup>2</sup> and the current study, the data was divided into three zones, with each zone containing an approximately equal number of articles. Equal article distribution division successfully resulted in three zones where the number of articles is almost accurately one-third of the total article count (approximately 33.33% each). In first zone, 1 (1.90%) journal published 3247 (33.22%) papers, followed by 413 (15.06%)

journals contribute 3259 (33.34%) papers in the second zone and 2278 (83.05%) journals contribute 3268 (33.44%) papers in the third zone. It can be observed that the three zones each account approximately one third of the sum number of articles shown Table-2 and Figur-3.

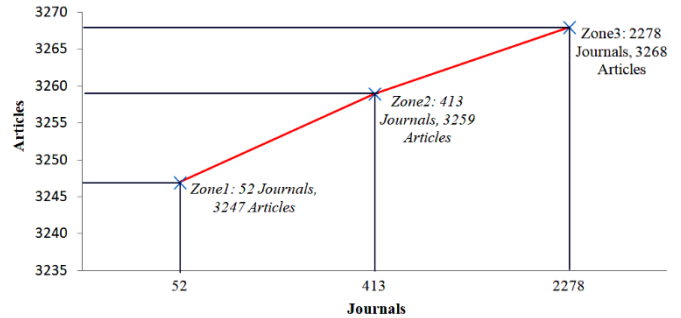


Figure-3: Scattering of journals in Bradford's law of Artificial Intelligence research output

Bradford's Law states that if journals are arranged in decreasing order of productivity on a given topic, they can be divided into a nucleus and several subsequent zones each are containing approximately the same number of relevant articles.

The number of journals in these zones follows a geometric sequence described by the formula:

- **Nucleus Zone:** The study found 1 journal in the core nucleus zone.
- **Bradford's Multiplier (n):** The mean value of Bradford's multiplier (n) derived from the study is n = 52.
- **The Geometric Sequence:** The relationship between the number of journals in the zones is confirmed as: 1 : n : n<sup>2</sup> OR 1 : 52 : 522

The sequence 52 : 349.91 : 2354.55 given as the "connection of every zone" likely refers to the number of articles or citations found within each zone, rather than the number of journals. This is a common method for validating Bradford's Law, as the law requires the output (articles) to be roughly equal in each zone, even though the input (journals) follows the geometric progression 1:n:n<sup>2</sup>. (Bradford, 1934).

- Zone 1 = 52
- Zone 2 = 349.91
- Zone 3 = 2354.55

$$\% \text{ error} = \frac{2756.46 - 2743}{2743} \times 100 = 0.490569$$

Observation the percentage of the error is negative and negligible (0.490569), therefore the data conforms well fit to Bradford's law zone.



2023 recorded the largest number of publications totaling 2104 (21.53%).

This research analysis of highly cited papers highlights that journal quality and impact are not solely determined by the volume of published works. While “Multimedia Tools and Applications” leads in the sheer number of highly cited papers (330), its Average Citation per Paper (ACPP) of 6.85 is the lowest among the featured journals. Especially the highly specialized “Expert Systems with Applications” maximum ACPP of 36.0 and demonstrate superior quality and relative impact, despite publishing fewer highly cited papers.

Equal article distribution division successfully resulted in three zones where the number of articles is almost accurately one-third of the total article count (approximately 33.33% each). In first zone, 1 (1.90%) journal published 3247 (33.22%) papers, followed by 413 (15.06%) journals contribute 3259 (33.34%) papers in the second zone and 2278 (83.05%) journals contribute 3268 (33.44%) papers in the third zone. The analysis strongly indicates that the data conforms well to Bradford's Law as evidenced by a negligible negative error percentage (0.49%).

Core Journals (1.26% of journals) contribute a substantial 27.77% of the articles. The Second Zone (10.53% of journals) adds another 32.28% of the articles. The Outermost Zone (88.21% of journals) accounts for the remaining 39.95% of the articles. This clear stratification confirms the concentration of key literature in a small core of highly productive journals.

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