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Research Outputs Of The Older Indian Institutes Of Technology (IITs) During Last 50 Years – Analysis With Reference to Web Of Science

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1. Introduction :

The **Indian Institutes of Technology (IITs)** have been recognized all over the world as centers of excellence in study and research in the fields of engineering and technology. The Indian Institutes of Technology owe their existence to the vision of late Pandit Jawaharlal Nehru, who first mooted the idea of establishing institutions of excellence to impart teaching and to guide research in technical and professional education of higher learning in India so as to produce trained technical manpower of world class and engage them in building modern India.

The IIT systems was founded by the Government of India in 1950 and raised to an "Institution of National Importance" by Parliament by means of the Indian Institute of Technology (Kharagpur) Act of 1956. The first Indian Institute of Technology was established in 1951 at Kharagpur, followed by IIT Bombay (1958), IIT Madras (1959), IIT Kanpur (1959) and IIT Delhi (1961) . Five years later, the Institutes of Technology Act,1961 was passed by Indian parliament declared these institutions as "Institutes of National Importance".

IITs maintain a unique education system model in India and are regarded as crown jewels for their contribution in teaching and research innovations at par with global standards particularly in engineering and technology. As productivity is the vital indicator of efficiency in any production system, the research productivity is also one of the dominating parameter for determining the academic credibility of an institution in terms of quantity, by counting of research articles published during a time period as well as quality, by analyzing the trend of citation.

The study attempts to provide a scholarly landscape of the five older Indian Institutes of Technology - IITs (established in Kharagpur, Bombay, Madras, Kanpur and Delhi) functioning for more than 50 years, through measuring the growth in publication of research articles as indexed in Web of Science during last 50 years (1970-2019), with analysis on top rated authorship, subject areas, collaboration with other institutions of national and international level and counties as well as the relevant issues on citation.

2. Literature Review :

The purpose of literature review is to offer an overview of the articles published on the relevant topic.

Though several studies have been conducted on measuring and assessment of research output, analyzing research productivity, bibliometic study, scientometric analysis, and citation impact on IITs and other institutions by different authors from time to time, a few such studies found relevant to the present investigation and deserve mention are as under :

i. A study made by ***Jeevan and Gupta*** (2002) [1] assessed and compared the impact of research publications of some of the departments of IIT Kharagpur for the period from 1994-95 to 1996-97 as per scientometric techniques.
ii. ***Wani et. al.***(2013) [2] attempted to gauge the research output of IIT Delhi for the period from 1964 to 2010 as indexed by SCOPUS and disclosed the average citation counts of the institution with highly cited subject fields .
iii. ***Prathap***(2013) [3] benchmarked the research performance of seven IITs using Web of Science and Scopus bibliometric databases.

iv. A bibliometric study made by ***Chaurasia*** and ***Chavan*** (2014) [4] attempted to focus on the growth, contribution and impact of research activity of IIT Delhi during the year 2001 to 2010 covered by Web of Science.

v. ***Hasan and Singh*** (2015) [5] evaluated the trend of research output of five top ranked IITs on the bases of the publication of research articles indexed in Web of Science for the period of five years (2009-13).

vi. ***Arif*** (2015) [6] in his study compared and contrasted the research productivity of the Computer Science and Engineering Department of four IITs over a period of five years (2011-2015) with DBLP, a computer science bibliography website.

vii. ***Hadimani et. al.***(2015) [7] conducted bibliometric analysis on research publications of IISER (Indian Institute of Science Education and Research), Thiruvananthapuram, India with the support of Web of Science database for the period from 2008-13.

viii. ***Bid*** (2016) [8] in his paper analyzed the growth and development of research activity of IIT Kharagpur during 2000 to 2015 as indexed in Scopus.

ix. ***Kumar et al*** (2018) [9] measured the research output of 23 IITs in India for the period of 29 years (1989-2018) as per the data available in Web of Science

x. ***Mohanty*** and ***Jena*** (2019) [10] conducted a scientometric analysis on the research output of IIT Bombay in the field of engineering during 2006-2016.

3. Objectivees :

- To measure the publication of research articles out of the documents published as well as year wise growth of publication by the five older Indian Institutes of Technology (IITs) in India during last 50 years (1970-2019);
- To examine the publication trend of research articles of each IIT in the blocks of every five years covering the total period of study;
- To review the citation profile of each IIT and gauge the citation impact in terms of h-index of individual IIT in time span of 50 years (1970-2019) breaking into the blocks of every five years;
- To measure the five top ratings of individual IIT in respect to research collaborations, country, authorship and research areas.

4. Methodology :

The data on research output of 5 older IITs for the last completed 50 yrs (1970-2019) as well as the data on publication of articles for a block of every five years for each IITs covering the total time span of study with different analyzed results were extracted from Web of Science database for interpretation.

5. Data Analysis and Interpretation

5.1 Publication Details

According to the data retrieved from the Web of Science (WOS) 5 older IITs published 1274481 documents as research output during last 50 completed years (1970-2019) in which 116713 were in the form of research articles. Table 1 presented the total number of documents as well as the articles published by individual IIT during the period of study with percentage and

ranking of the institutions. IIT Kharagpur achieved 1st Rank in publishing 28822 (22.61%) documents of which 26688 (22.87%) were research articles followed by IIT Madras with the publication of 24236 (20.76%) research articles in total publication of 26398 (20.71) documents. The 3rd, 4th and 5th ranks were achieved by IIT Delhi (23914 – 20.49% research articles out of 26431 - 20.73% documents), IIT Bombay (21918 – 18.78% research articles out of 24001 – 18.83% documents) and IIT Kanpur (19957 – 17.10% research articles out of 21829 – 17.12% documents) respectively.

Table 1 : Publication of 5 IITs during last 50 years (1970-2019)

IITs	Documents Published	%	Articles Published	%	Rank
IIT Kharagpur	28822	22.61	26688	22.87	1
IIT Bombay	24001	18.82	21918	18.78	4
IIT Madras	26398	20.71	24236	20.76	2
IIT Kanpur	21829	17.12	19957	17.10	5
IIT Delhi	26431	20.73	23914	20.49	3
Total Pub. Of 5 IITs	**127481**	**100.00**	**116713**	**100.00**	

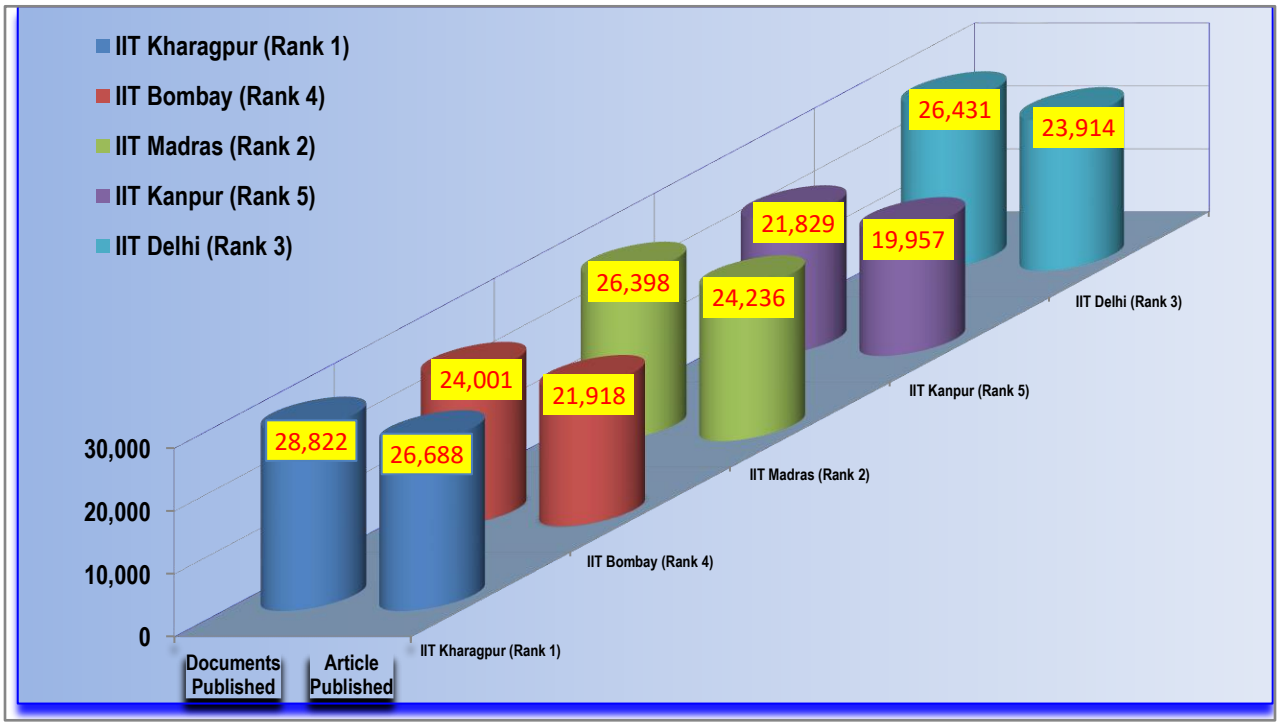


Fig. 1: Trend of publication of 5 IITs during last 50 years (1970-2019) with Ranking

5.2 Year-wise Distribution of Publications

The year-wise publication of research articles of 5 IITs in the time span of 50 competed years (1970-2019) are displayed in Table 2.

Table 2 : Year-wise Distribution of Publications by 5 IITs during last 50 years (1970-2019)

Years	Article Pub.- Year Wise	% of Total Article Pub. In 50 Yrs	CAGR	Article Pub.- Year Wise	% of Total Article Pub. In 50 Yrs	CAGR	Article Pub.- Year Wise	% of Total Article Pub In 50 Yrs.	CAGR	Article Pub.- Year Wise	% of Total Article Pub In 50 Yrs.	CAGR	Article Pub.- Year Wise	% of Total Article Pub In 50 Yrs	CAGR
	IIT Kharagpur			IIT Bombay			IIT Madras			IIT Kanpur			IIT Delhi		
1970	1	0.004 %		1	0.005 %		0	0..00%		20	0.100 %		5	0.021 %	
1971	0	0.0%		0	0.00%		0	0.00%		5	0.025 %		1	0.004 %	
1972	10	0.037 %		9	0.041 %		11	0.045 %		22	0.110 %		16	0.067 %	
1973	86	0.322 %		71	0.324 %		160	0.660 %		138	0.691 %		140	0.585 %	
1974	96	0.360 %		75	0.342 %		129	0.532 %		142	0.712 %		135	0.565 %	
1975	110	0.412 %		79	0.360 %		145	0.598 %		166	0.832 %		150	0.627 %	
1976	109	0.408 %		100	0.456 %		147	0.607 %		157	0.787 %		157	0.657 %	
1977	136	0.510 %		113	0.516 %		151	0.623 %		175	0.877 %		142	0.594 %	
1978	154	0.577 %		150	0.684 %		150	0.619 %		172	0.862 %		155	0.648 %	
1979	138	0.517 %		134	0.611 %		165	0.681 %		200	1.002 %		251	1.050 %	
1980	164	0.615 %		139	0.634 %		156	0.644 %		189	0.947 %		233	0.974 %	
1981	134	0.502 %		143	0.652 %		180	0.743 %		212	1.062 %		247	1.033 %	
1982	194	0.727 %		164	0.748 %		173	0.714 %		220	1.102 %		286	1.196 %	
1983	173	0.648 %		147	0.671 %		209	0.862 %		222	1.112 %		321	1.342 %	
1984	195	0.731 %		153	0.698 %		204	0.842 %		203	1.017 %		310	1.296 %	
1985	181	0.678 %		167	0.762 %		197	0.813 %		205	1.027 %		311	1.300 %	
1986	213	0.798 %		161	0.735 %		211	0.871 %		217	1.087 %		293	1.225 %	
1987	203	0.761 %		161	0.735 %		243	1.003 %		196	0.982 %		303	1.267 %	
1988	182	0.682 %		150	0.684 %		248	1.023 %		188	0.942 %		297	1.242 %	
1989	212	0.794 %		167	0.762 %		262	1.081 %		207	1.037 %		263	1.100 %	
1990	254	0.952 %		185	0.844 %		251	1.036 %		173	0.867 %		263	1.100 %	
1991	263	0.985 %		212	0.967 %		257	1.060 %		235	1.178 %		289	1.208 %	
1992	297	1.113 %		221	1.008 %		273	1.126 %		193	0.967 %		270	1.129 %	
1993	302	1.132 %		193	0.881 %		339	1.399 %		240	1.203 %		259	1.083 %	
1994	299	1.120 %		233	1.063 %		337	1.390 %		236	1.183 %		335	1.401 %	
1995	300	1.124 %		259	1.182 %		375	1.547 %		266	1.333 %		316	1.321 %	
1996	336	1.259 %		302	1.378 %		416	1.716 %		299	1.498 %		335	1.401 %	
1997	360	1.349 %		342	1.560 %		398	1.642 %		309	1.548 %		306	1.280 %	
1998	340	1.274 %		302	1.378 %		394	1.626 %		346	1.734 %		365	1.526 %	
1999	444	1.664 %		293	1.337 %		365	1.506 %		312	1.563 %		307	1.284 %	
2000	406	1.521 %		351	1.601 %		345	1.424 %		331	1.659 %		339	1.418 %	
2001	422	1.581 %		356	1.624 %		304	1.254 %		334	1.674 %		357	1.493 %	
2002	428	1.604 %		365	1.665 %		310	1.279 %		379	1.899 %		367	1.535 %	
2003	482	1.806 %		395	1.802 %		368	1.518 %		422	2.115 %		467	1.953 %	
2004	601	2.252 %		483	2.204 %		410	1.692 %		487	2.440 %		518	2.166 %	
2005	657	2.462 %		512	2.336 %		537	2.216 %		496	2.485 %		586	2.450 %	
2006	833	3.121 %		580	2.646 %		613	2.529 %		592	2.966 %		660	2.760 %	
2007	943	3.533 %		656	2.993 %		723	2.983 %		650	3.257 %		766	3.203 %	
2008	1,004	3.762 %		656	2.993 %		798	3.293 %		724	3.628 %		775	3.241 %	
2009	1,091	4.088 %		709	3.235 %		789	3.255 %		693	3.472 %		756	3.161 %	
2010	1,094	4.099 %		745	3.399 %		899	3.709 %		652	3.267 %		800	3.345 %	
2011	1,012	3.792 %		788	3.595 %		928	3.829 %		698	3.498 %		761	3.182 %	
2012	1,077	4.036 %		863	3.937 %		843	3.478 %		707	3.543 %		806	3.370 %	
2013	1,183	4.433 %		977	4.458 %		901	3.718 %		771	3.863 %		942	3.939 %	
2014	1,289	4.830 %		1,100	5.019 %		996	4.110 %		840	4.209 %		1,044	4.366 %	
2015	1,412	5.291 %		1,202	5.484 %		1,181	4.873 %		910	4.560 %		1,045	4.370 %	
2016	1,547	5.797 %		1,333	6.082 %		1,336	5.512 %		1,025	5.136 %		1,256	5.252 %	
2017	1,587	5.946 %		1,535	7.003 %		1,566	6.461 %		1,086	5.442 %		1,435	6.001 %	
2018	1,740	6.520 %		1,659	7.569 %		1,792	7.394 %		1,137	5.697 %		1,461	6.109 %	
2019	1,994	7.472 %		1,827	8.336 %		2,051	8.463 %		1,158	5.802 %		1,712	7.159 %	
Total	26,688	100%		21,918	100%		24,236	100%		19,957	100%		23,914	100%	
			16.41 %			16.21 %			11.02 %			8.46 %			12.38 %

The Compound Annual Growth Rate (CAGR) of the research productivity derived from the year-wise growth in the publication of research articles of each IIT is mentioned in the above table that

determines the annual growth rate of the individual institution for a specific span of time where the value fluctuates from one period to the next.

$$CACR(t_0, t_n) = \left(\frac{V(t_n)}{V(t_0)} \right)^{\frac{1}{t_n - t_0}} - 1$$

where, $V(t_0)$: start value, $V(t_n)$ finish value, $t_n - t_0$: number of years.

The growth rate of IIT Kharagpur (16.41%) found to be the highest among the 5 IITs followed by IIT Bombay (16.21%), IIT Delhi (12.38%), IIT Madras (11.02%) and IIT Kanpur (8.46%)

5.3 Ranking of IITs in Different Block Years based on Publication of Research Articles

To have a precise view on the publication of articles by 5 IITs, the total period of study is divided into ten blocks of five years each as shown in Table 3 and ranked the institutions in different block periods for better visualization of the ups and downs of research productivity of each IIT. IIT Kanpur ranked 1 in first two consecutive blocks but dropped subsequently. IIT Delhi and IIT Madras ranked 1 in block 3 & 4 and 5 & 6 respectively. The trend of improvement in research productivity is noticed in IIT Kharagpur as mentioned in the following table and rapidly achieved Rank 1 in four consecutive years from block 7 to 10. The improvement in productivity is also noticed in case of IIT Bombay but the institution is yet to achieve Rank 1.

Fig. 2: Ranking of 5 IITs in Different Block Years based

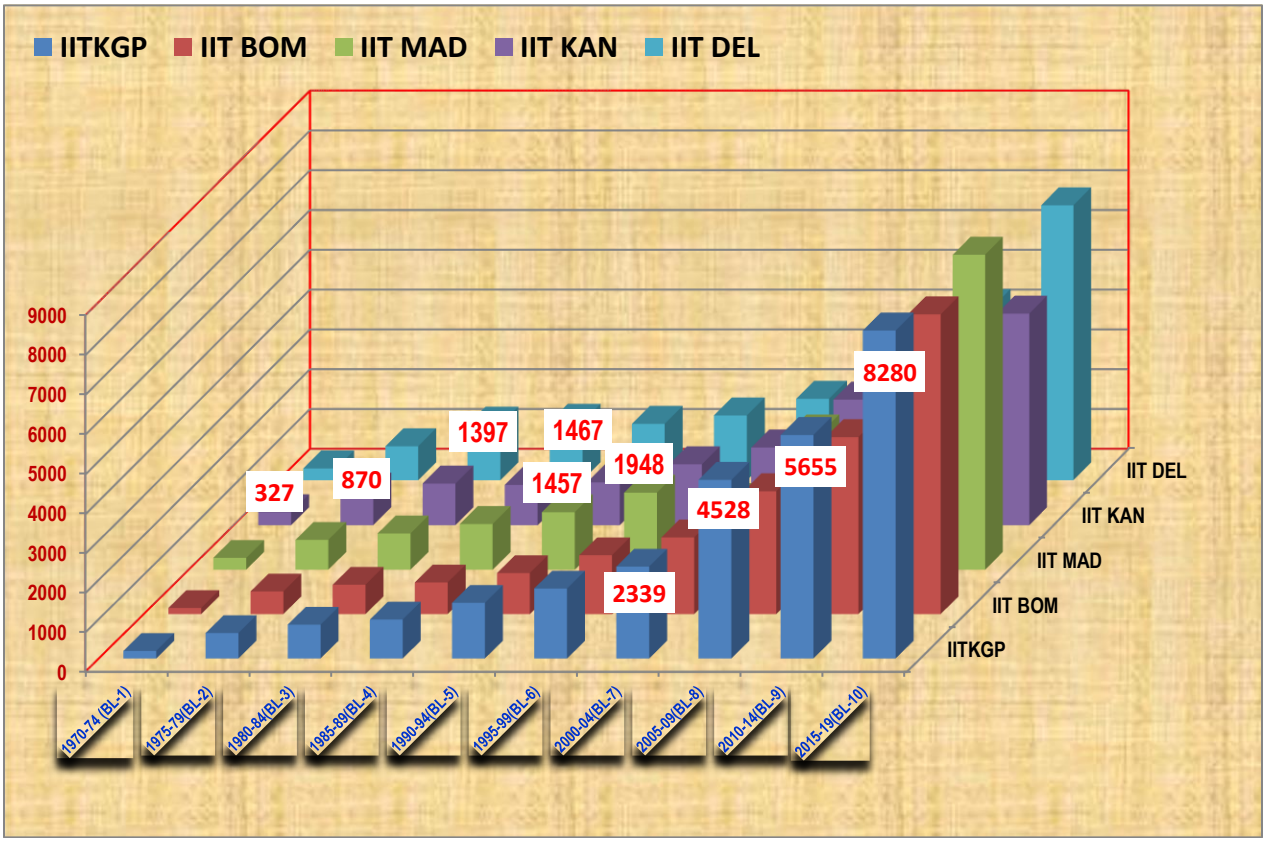


Table 3 : Ranking of 5 IITs in Different Block Years based on Publication Trend

Block of 5 Years		IIT Kharagpur		IIT Bombay		IIT Madras		IIT Kanpur		IIT Delhi	
		Pub.	Rank	Pub.	Rank	Pub.	Rank	Pub.	Rank	Pub.	Rank
Block 1	**1970-1974**	193	**4**	156	**5**	300	**2**	327	**1**	297	**3**
Block 2	**1975-1979**	647	**4**	576	**5**	758	**3**	870	**1**	855	**2**
Block 3	**1980-1984**	860	**4**	746	**5**	922	**3**	1046	**2**	1397	**1**
Block 4	**1985-1989**	991	**4**	806	**5**	1161	**2**	1013	**3**	1467	**1**
Block 5	**1990-1994**	1415	**3**	1044	**5**	1457	**1**	1077	**4**	1416	**2**
Block 6	**1995-1999**	1780	**2**	1498	**5**	1948	**1**	1532	**4**	1629	**3**
Block 7	**2000-2004**	2339	**1**	1950	**4**	1737	**5**	1953	**3**	2048	**2**
Block 8	**2005-2009**	4528	**1**	3113	**5**	3460	**3**	3155	**4**	3543	**2**
Block 9	**2010-2014**	5655	**1**	4473	**3**	4567	**2**	3668	**5**	4353	**4**
Block 10	**2015-2019**	8280	**1**	7556	**3**	7926	**2**	5316	**5**	6909	**4**
Total Articles Published in 50 Yrs (1970-2019)		**26688**		**21918**		**24236**		**19957**		**23914**	

5.4 Citation Profile of 5 IITs in Different Block Years

The citation based measurements of the 5 older IITs in different block years covering the total time span of 50 years are presented institution-wise in the following Tables (Table 4 to Table 8).

Table 4 : Citation Profile of IIT Kharagpur

Block of 5 Years		TP	TC	CA	ACPA	h-index
Block 1	1970-1974	193	1303	1197	6.75	18
Block 2	1975-1979	647	4867	4155	7.52	29
Block 3	1980-1984	860	7994	6278	9.30	38
Block 4	1985-1989	991	9818	8119	9.91	43
Block 5	1990-1994	1415	17304	14105	12.23	54
Block 6	1995-1999	1780	29813	24704	16.75	69
Block 7	2000-2004	2339	63896	52412	27.32	102
Block 8	2005-2009	4528	126123	99661	27.85	126
Block 9	2010-2014	5655	114213	89913	20.20	97
Block 10	2015-2019	8280	74151	57569	8.96	65

TP : Total Publication of Articles; TC : Total Citations; CA : Citing Articles; ACP Average Citation Per Article;

Table 5 : Citation Profile of IIT Bombay

Block of 5 Years		TP	TC	CA	ACPA	h-index
Block 1	1970-1974	156	1479	1300	9.48	19
Block 2	1975-1979	576	4970	4346	8.63	33
Block 3	1980-1984	746	6091	5303	8.16	33
Block 4	1985-1989	806	8265	7055	10.25	40
Block 5	1990-1994	1044	14072	11821	13.48	46
Block 6	1995-1999	1498	26460	22412	17.64	69
Block 7	2000-2004	1950	51239	42504	26.28	90
Block 8	2005-2009	3113	86966	69774	27.94	110
Block 9	2010-2014	4473	103688	77604	23.18	113
Block 10	2015-2019	7556	74278	53714	9.83	71

TP : Total Publication of Articles; TC : Total Citations; CA : Citing Articles; ACP Average Citation Per Article;

Table 6 : Citation Profile of IIT Madras

Block of 5 Years		TP	TC	CA	ACPA	h-index
Block 1	1970-1974	300	1807	1628	6.02	21
Block 2	1975-1979	758	5488	4881	7.24	30
Block 3	1980-1984	922	6640	5685	7.20	30
Block 4	1985-1989	1161	9764	8474	8.41	39
Block 5	1990-1994	1457	15700	13729	10.78	47
Block 6	1995-1999	1948	29736	25993	15.26	72
Block 7	2000-2004	1737	43726	37700	25.17	89
Block 8	2005-2009	3460	88824	74727	25.67	110
Block 9	2010-2014	4567	94924	76714	20.78	108
Block 10	2015-2019	7926	72926	51759	9.20	68

TP : Total Publication of Articles; TC : Total Citations; CA : Citing Articles; ACP Average Citation Per Article;

Table 7 : Citation Profile of IIT Kanpur

Block of 5 Years		TP	TC	CA	ACPA	h-index
Block 1	1970-1974	327	4153	3801	12.70	33
Block 2	1975-1979	870	11015	9682	12.66	43
Block 3	1980-1984	1046	10225	8389	9.78	40
Block 4	1985-1989	1013	12540	10571	12.38	41
Block 5	1990-1994	1077	15650	12994	14.53	48
Block 6	1995-1999	1532	32065	25897	20.93	76
Block 7	2000-2004	1953	80056	64987	40.99	105
Block 8	2005-2009	3155	83756	64594	26.55	109
Block 9	2010-2014	3668	70713	54262	17.28	85
Block 10	2015-2019	5316	45849	35172	8.62	57

TP : Total Publication of Articles; TC : Total Citations; CA : Citing Articles; ACP Average Citation Per Article;

Table 8: Citation Profile of IIT Delhi

Block of 5 Years		TP	TC	CA	ACPA	h-index
Block 1	1970-1974	297	2503	2188	8.43	23
Block 2	1975-1979	855	7157	6070	8.37	33
Block 3	1980-1984	1397	17017	14027	12.18	55
Block 4	1985-1989	1467	20068	17600	13.68	52
Block 5	1990-1994	1416	18372	15757	12.97	56
Block 6	1995-1999	1629	27701	23859	17.00	70
Block 7	2000-2004	2048	51282	43100	25.04	96
Block 8	2005-2009	3543	96273	78671	27.17	117
Block 9	2010-2014	4353	93054	74405	21.38	98
Block 10	2015-2019	6909	61123	47721	8.85	64

TP : Total Publication of Articles; TC : Total Citations; CA : Citing Articles; ACP Average Citation Per Article;

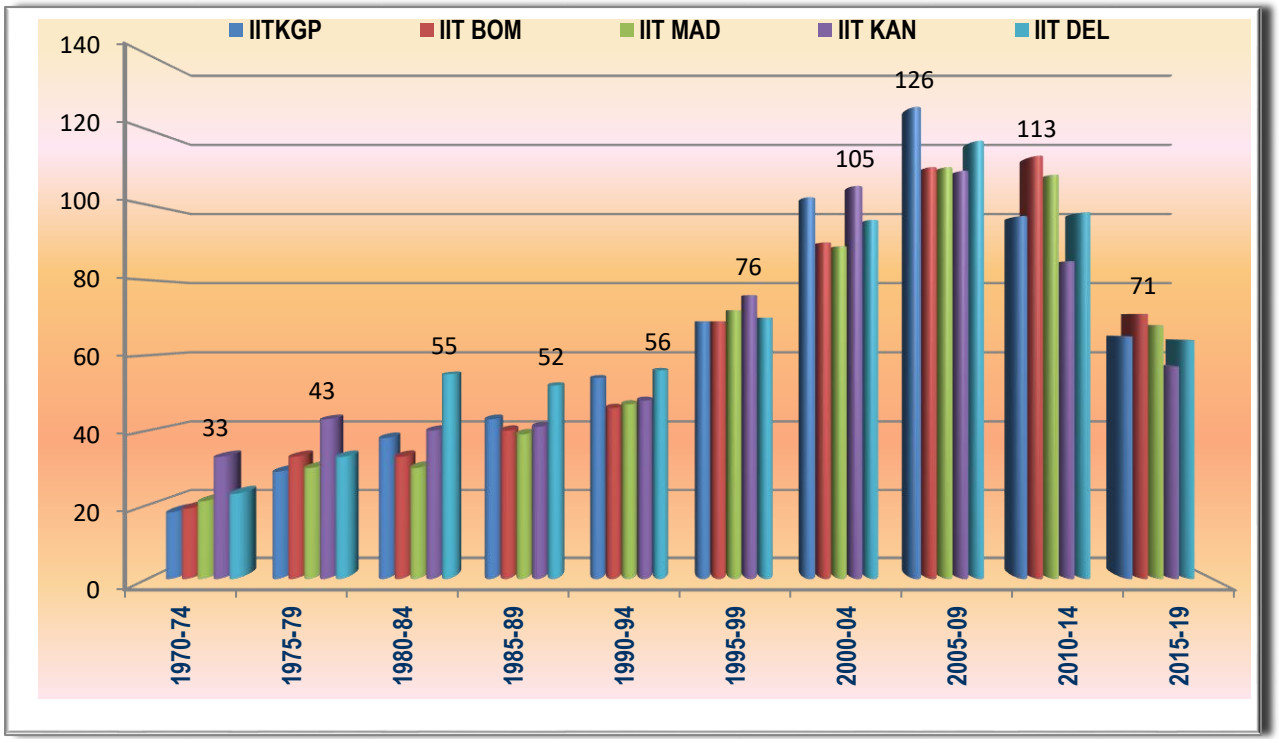
The citations-based values as presented in above five tables (Table 4 to 8) depict the appreciating performance of different institutions in different block years. In order to rank the research performance of 5 IITs on the basis of the derived h-index, the combination of quantity and quality of research publications, as reported in different tables, are combined in Table 9.

Table 9 : Ranking of 5 IITs in different block years as per h-index values

Block of 5 Years		IIT Kharagpur		IIT Bombay		IIT Madras		IIT Kanpur		IIT Delhi	
		h-index	Rank	h-index	Rank	h-index	Rank	h-index	Rank	h-index	Rank
Block 1	1970-1974	18	5	19	4	21	3	33	1	23	2
Block 2	1975-1979	29	4	33	2	30	3	43	1	33	2
Block 3	1980-1984	38	3	33	4	30	5	40	2	55	1
Block 4	1985-1989	43	2	40	4	39	5	41	3	52	1
Block 5	1990-1994	54	2	46	5	47	4	48	3	56	1
Block 6	1995-1999	69	4	69	4	72	2	76	1	70	3
Block 7	2000-2004	102	2	90	4	89	5	105	1	96	3
Block 8	2005-2009	126	1	110	3	110	3	109	4	117	2
Block 9	2010-2014	97	4	113	1	108	2	85	5	98	3
Block 10	2015-2019	65	3	71	1	68	2	57	5	64	4

Table 9 shows the highest h-index value in favour of IIT Kanpur in the Block Years 1 and 2, whereas IIT Delhi achieved the highest rank consecutively in three Block years 3, 4 and 5. Again in Block Years 6 and 7, IIT Kanpur scored highest h-index values and in the Block Year 8, IIT Kharagpur reached the first rank with h-index value 126 which was found to be the highest value among all the Block Years, i.e. 50 years. The h-index value of IIT Bombay witnessed rank 1 in the Block Years 9 and 10. The highest h-index value of each Block Year with the institution performed is specified in Fig. 3. The h-index value of individual IIT in every Block Year row in Table 9 shows competitive and impressive research performance during a prolonged period of 50 years.

Fig. 3 : Highest h-index value in each Block Year with the Institution Performed



5.5 Collaboration with National Institutions

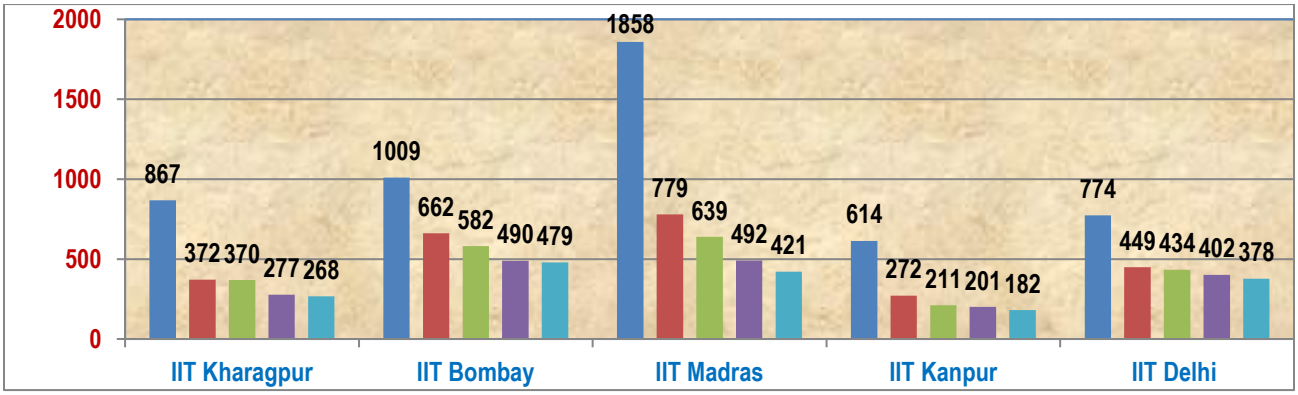
In terms of collaboration in article publications of 5 IITs with top five institutions at national level during 1970-2019 are displayed in Table 10 and plotted in Fig.4. Out of the total publications of each IIT, IIT Madras published 1858 articles in collaboration with CSIR, India which is found to be the highest among all 5 IITs followed by IIT Bombay published 1009 articles in collaboration with BARC, India. The IITs published articles in collaboration with other reputed Indian institutions like TFIR, DRDO, DST, NPL, IISc Bangalore etc. Table 10 and Fig.4 illustrate that highest number collaborative publications of 4 IITs – IIT Madras(1858 – 7.666% of TP), IIT Kharagpur (867 – 3.249% of TP), IIT Delhi (774 – 3.237%) and IIT Kanpur (614 – 3.077% of TP) with CSIR but IIT Bombay (1009 – 4.604% of TP), the scored highest counts published articles in collaboration with BARC.

Table 10 :Collaboration with National Institutions (Top Five)

S N	IIT Kharagpur			IIT Bombay			IIT Madras			IIT Kanpur			IIT Delhi		
	*TP : 26688			*TP : 21918			*TP : 24236			*TP : 19,957			*TP : 23914		
1	CSIR, India	867	3.249 %	BARC, India	1,009	4.604 %	CSIR, India	1,858	7.666 %	CSIR, India	614	3.077 %	CSIR , India	774	3.237 %
2	DST, India	372	1.394 %	TIFR, India	662	3.020 %	TIFR, India	779	3.214 %	IISc Bangalore	272	1.363 %	DRDO, India	449	1.878 %
3	Jadavpur University	370	1.386 %	CSIR, India	582	2.655 %	IISc, Bangalore	639	2.637 %	TIFR, India	211	1.057 %	NPL, India	434	1.815 %
4	DRDO, India	277	1.038 %	DST, India	490	2.236 %	Punjab University	492	2.030 %	DST, India	201	1.007 %	University of Delhi	402	1.681 %
5	IIEST, Shibpur	268	1.004 %	IOP, Bhubaneswar	479	2.185 %	IIT Bhubaneswar	421	1.737 %	IIT Bombay	182	0.912 %	AIIMS, New Delhi	378	1.581 %

*TP : Total Published Articles during 1970-2019

Fig. 4 : Publication of Articles of 5 IITs in Collaboration with National Institutions (Top Five)



5.6 Collaboration with International Institutions

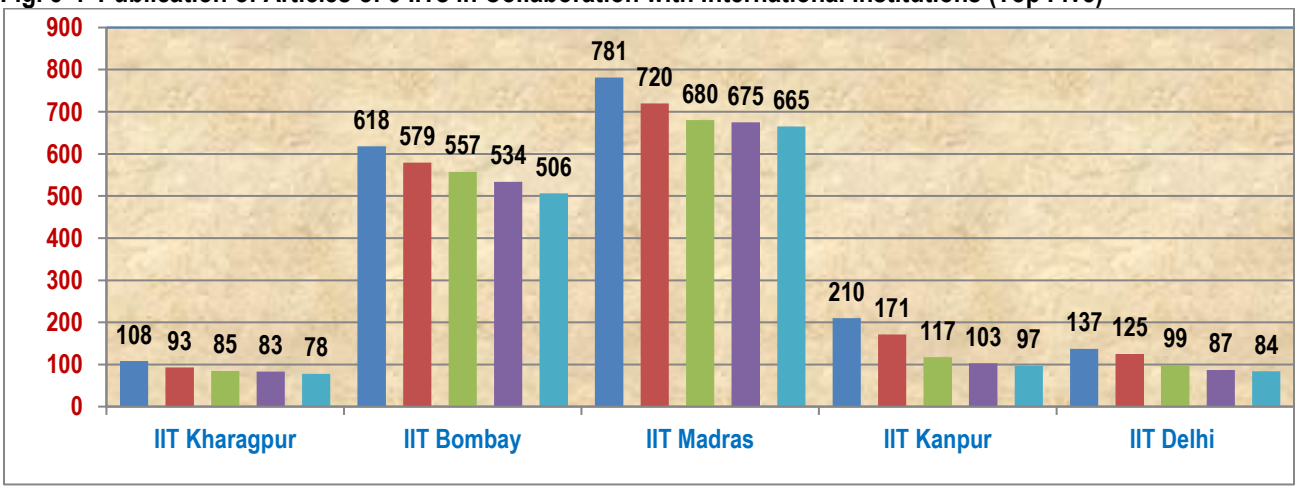
The publication of articles of 5IITs during last 50 years in collaboration with top five international institutions are expressed in Table 11 and plotted in Fig. 5.

Table 11 :Collaboration with International Institutions (Top Five)

SN	IIT Kharagpur			IIT Bombay			IIT Madras			IIT Kanpur			IIT Delhi		
	*TP : 26688			*TP : 21918			*TP : 24236			*TP : 19,957			*TP : 23914		
1	HELMHOLTZ ASSOCIATION	108	0.405 %	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS	618	2.820 %	HELMHOLTZ ASSOCIATION	781	3.222 %	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS	210	1.052 %	INTERNATIONAL BUSINESS MACHINES IBM	137	0.573 %
2	MAX PLANCK SOCIETY	93	0.348 %	UNITED STATES DEPARTMENT OF ENERGY DOE	579	2.642 %	RUSSIAN ACADEMY OF SCIENCES	720	2.971 %	UNIVERSITY OF CALIFORNIA SYSTEM	171	0.857 %	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS	125	0.523 %
3	UNIVERSITY OF KWAZULU NATAL	85	0.318 %	UNIVERSITY OF CALIFORNIA SYSTEM	557	2.541 %	CHINESE ACADEMY OF SCIENCES	680	2.806 %	MAX PLANCK SOCIETY	117	0.586 %	UNIVERSITY OF CALIFORNIA SYSTEM	99	0.414 %
4	UNITED STATES DEPARTMENT OF ENERGY DOE	83	0.311 %	UNIVERSITY OF TEXAS SYSTEM	534	2.436 %	ISTITUTO NAZIONALE DI FISICA NUCLEAREINFN	675	2.785 %	UNIVERSITY OF TEXAS SYSTEM	103	0.516 %	MAX PLANCK SOCIETY	87	0.364 %
5	LEIBNIZ INSTITUT FUR POLYMERFORSCHUNG DRESDEN	78	0.292 %	CZECH ACADEMY OF SCIENCES	506	2.309 %	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS	665	2.744 %	HELMHOLTZ ASSOCIATION	97	0.486 %	UNIVERSITY SYSTEM OF MARYLAND	84	0.351 %

***TP : Total Published Articles during 1970-2019**

Fig. 5 : Publication of Articles of 5 IITs in Collaboration with International Institutions (Top Five)



Among 5 IITs, IIT Madras published maximum number articles in collaboration with international institution – Helmholtz Association (781 – 3.222% of TP) followed by IIT Bombay with Centre National De La Recherche Scientifique, CNRS (618 – 2.820% of TP). The overall international collaborative publication of articles of IIT Kharagpur (108), IIT Kanpur (210) and IIT Delhi (137) found to be comparatively less than IIT Madras and IIT Bombay as shown in Table 11 and graphed in Fig.5.

5.7 Collaboration with Different Countries

The collaborative linkages of each IIT with different countries (top five) in publication of the articles during last 50 years presented in descending order as shown in Table 12 and Fig. 6. The record counts given in the table stated that all the 5 IITs maintained the highest collaboration with USA followed by Germany in articles publication and subsequently with other leading countries like England, Canada, China, France etc. IIT Bombay achieved the highest collaborative linkage with USA (2506 – 11.434% of TP) followed by IIT Madras (2205 – 9.098% of TP), IIT Kanpur (1844 – 9.240% of TP), IIT Delhi (1465 – 6.126% of TP) and IIT Kharagpur (1459 – 5.467% of TP). Again IIT Madras scored maximum in collaborative linkage with Germany (1384 – 5.711% of TP) followed by IIT Bombay (1233 – 5.626% of TP), IIT Kharagpur (716 – 2.683% of TP), IIT Kanpur (581 – 2.911% of TP) and IIT Delhi (494 – 2.066% of TP).

Fig. 6 : Publication of Articles by 5 IITs in Collaboration with Different Countries (Top Five)

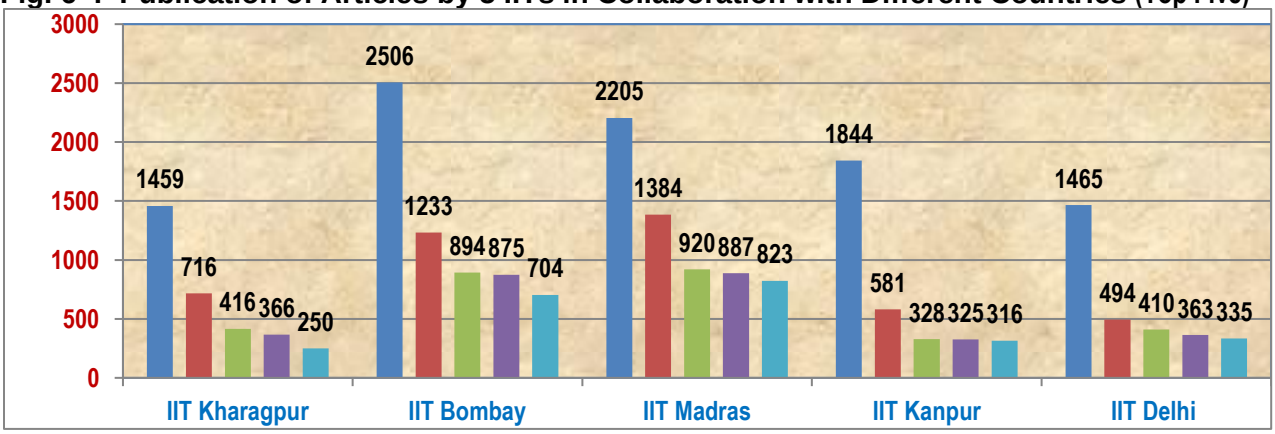


Table 12 : Collaboration with Different Countries (Top Five)

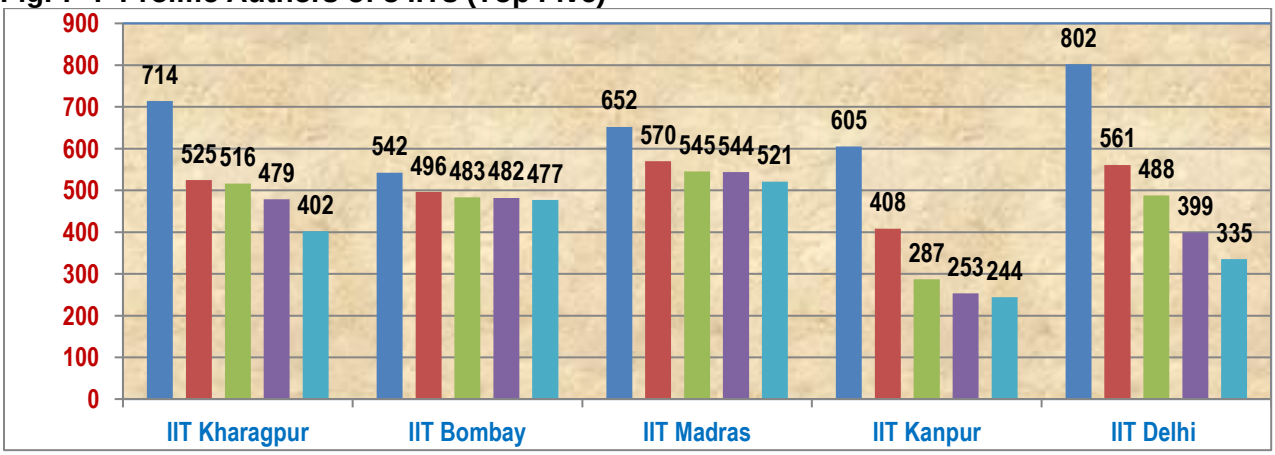
SN	IIT Kharagpur *TP : 26688			IIT Bombay *TP : 21918			IIT Madras *TP : 24236			IIT Kanpur *TP : 19,957			IIT Delhi *TP : 23914		
1	USA	1,459	5.467 %	USA	2,506	11.434 %	USA	2,205	9.098 %	USA	1,844	9.240 %	USA	1,465	6.126 %
2	GERMANY	716	2.683 %	GERMANY	1,233	5.626 %	GERMANY	1,384	5.711 %	GERMANY	581	2.911 %	GERMANY	494	2.066 %
3	ENGLAND	416	1.559 %	FRANCE	894	4.079 %	SOUTH KOREA	920	3.796 %	ENGLAND	328	1.644 %	ENGLAND	410	1.714 %
4	CANADA	366	1.371 %	ENGLAND	875	3.992 %	PEOPLES R CHINA	887	3.660 %	CANADA	325	1.629 %	CANADA	363	1.518 %
5	JAPAN	250	0.937 %	PEOPLES R CHINA	704	3.212 %	RUSSIA	823	3.396 %	FRANCE	316	1.583 %	FRANCE	335	1.401 %

*TP : Total Published Articles during 1970-2019

5.8 Prolific Authors

Top five prolific authors of 5 IITs are traced in Fig. 7 as observed in the Table 13.

Fig. 7 : Prolific Authors of 5 IITs (Top Five)



Out of individual contribution from 5 IITs, A. Kumar of IIT Delhi published 802 articles, 3.354% of total publications of IIT Delhi and found to be the highest among all the contributors all the 5 IITs

during last 50 years. The second highest contributor S. Chakraborty of IIT Kharagpur published 714 articles, followed by S. Ghosh of IIT Madras contributed 652 articles. A. Kumar of IIT Kanpur and A. Gupta of IIT Bombay published 605 and 542 articles respectively.

Table 13 : Prolific Authors of 5 IITs (Top Five)

SN	IIT Kharagpur			IIT Bombay			IIT Madras			IIT Kanpur			IIT Delhi		
	*TP : 26688			*TP : 21918			*TP : 24236			*TP : 19,957			*TP : 23914		
1	CHAKRABORTY S	714	2.675 %	GUPTA A	542	2.473 %	GHOSH S	652	2.690 %	KUMAR A	605	3.032 %	KUMAR A	802	3.354 %
2	DAS S	525	1.967 %	VARMA R	496	2.263 %	CHOI Y	570	2.352 %	SHARMA A	408	2.044 %	SINGH B	561	2.346 %
3	BHOWMICK A K	516	1.933 %	DAS D	483	2.204 %	HOU W S	545	2.249 %	CHANDRASEKHAR V	287	1.438 %	KUMAR S	488	2.041 %
4	GHOSH S	479	1.795 %	GHOSH P	482	2.199 %	MOHANTY G B	544	2.245 %	CHHABRA R P	253	1.268 %	TIWARI G N	399	1.668 %
5	CHOUDHARY R N P	402	1.506 %	NANDI B K	477	2.176 %	KUMAR R	521	2.150 %	KUMAR S	244	1.223 %	SHARMA S	329	1.376 %

***TP : Total Published Articles during 1970-2019**

5.9 Research Areas of 5 IITs (Top Five)

Research performance of the 5 older IITs in academic research covering the areas of engineering science and technology has earned distinguishing position over time. The research productivity of individual IIT in different subject areas are listed in Table 14 and indicated in Fig. 8. As observed from the following table and figure that apart from research performance in Engineering, IITs also play a leading role in the distinct branches of Science like Physics, Chemistry, Materials Science etc. IITs other than IIT Kanpur contributed highest number of articles in engineering individually in the top five productive research areas during last 50 years. IIT Madras contributed highest research publications in Engineering (7906) among all institutions followed by IIT Kharagpur (7834), IIT Delhi (7329), IIT Bombay (5843). Subsequent leading research areas of IIT Kharagpur, IIT Bombay, IIT Madras and IIT Delhi are Materials Science (5420), Chemistry (5148), Chemistry 5089) and Physics (4163) respectively. For IIT Kanpur, top

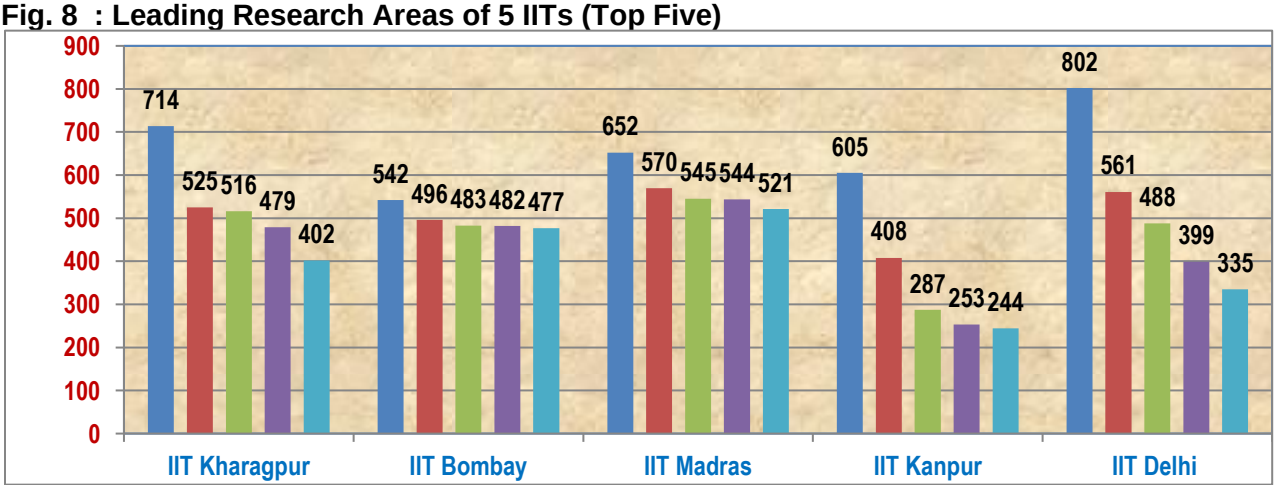
five productive research areas started with Chemistry (5029 – 25.199% of TP) followed by engineering (4877).

Table 14 : Leading Research Areas of 5 IITs (Top Five)

SN	IIT Kharagpur			IIT Bombay			IIT Madras			IIT Kanpur			IIT Delhi		
	*TP : 26688			*TP : 21918			*TP : 24236			*TP : 19,957			*TP : 23914		
1	ENGINEERING	7,834	29.354 %	ENGINEERING	5,843	26.658 %	ENGINEERING	7,906	32.621 %	CHEMISTRY	5,029	25.199 %	ENGINEERING	7,329	30.647 %
2	MATERIALS SCIENCE	5,429	20.342 %	CHEMISTRY	5,148	23.488 %	CHEMISTRY	5,069	20.915 %	ENGINEERING	4,877	24.438 %	PHYSICS	4,163	17.408 %
3	CHEMISTRY	4,524	16.951 %	PHYSICS	4,909	22.397 %	MATERIALS SCIENCE	4,834	19.946 %	PHYSICS	4,772	23.911 %	MATERIALS SCIENCE	4,116	17.212 %
4	PHYSICS	4,387	16.438 %	MATERIALS SCIENCE	3,605	16.448 %	PHYSICS	4,806	19.830 %	MATERIALS SCIENCE	3,514	17.608 %	CHEMISTRY	3,534	14.778 %
5	POLYMER SCIENCE	2,131	7.985 %	SCIENCE TECHNOLOGY OTHER TOPICS	1,470	6.707 %	MECHANICS	1,929	7.959 %	MATHEMATICS	1,420	7.115 %	ENERGY FUELS	1,891	7.908 %

*TP : Total Published Articles during 1970-2019

Fig. 8 : Leading Research Areas of 5 IITs (Top Five)



6. Research Findings

1) Steady increase in a academic research output of 5 older IITs was evident during last 50 years (1970-2019). Out of 1274481 documents published by the 5 older IITs, 116713 were found in the form of research articles. Among the older IITs, IIT Kharagpur achieved 1st rank publishing 26688 research articles out of 28822 total documents in different forms, followed by IIT Madras (24236 research articles out of total 26398 published documents), IIT Delhi (23914 research articles out of total publication of 26431 documents), IIT Bombay (21918 research articles out of 24001 total documents published) and IIT Kanpur (19957 research articles out of 21829 documents published).

2) In order to monitor the publication trend of 5 older IITs during 1970-2019, counting of the productivity for the blocks of every five years for each IITs was derived which disclosed highest or progressive ranking of individual IITs in different block years.

3) The highest h-index value of each Block Year with the institution performed was retrieved. The h-index value of different IITs in different Block Years depicts competitive and impressive research performance of the institutions during the vast span of 50 years.

4) Regarding collaboration in articles publications with the institutions at national level, IIT Madras performed the highest (1858 articles) followed by IIT Bombay (1009), IIT Kharagpur (867), IIT Delhi (774), IIT Kanpur (614). The IITs published articles in collaboration with reputed Indian institutions like CSIR,TFIR, DRDO, DST, IISc Bangalore etc.

5) In collaboration with international institution IT Madras published maximum number of articles with Helmholtz Association (781 – 3.222% of TP) followed by IIT Bombay with Centre National De La Recherche Scientifique, CNRS (618 – 2.820% of TP). The overall international collaborative publication of articles of IIT Kharagpur (108), IIT Kanpur (210) and IIT Delhi (137) found to be comparatively less than IIT Madras and IIT Bombay.

6) All the 5 older IITs maintained the highest collaboration in articles publication with USA followed by Germany as well as with other leading countries like England, Canada, China, France etc.

7) Out of individual contribution from 5 IITs, A. Kumar of IIT Delhi published 802 articles found to be the highest among all the contributors all the 5 IITs during last 50 years. The second highest contributor S. Chakraborty of IIT Kharagpur published 714 articles, followed by S. Ghosh of IIT Madras contributed 652 articles. A. Kumar of IIT Kanpur and A. Gupta of IIT Bombay published 605 and 542 articles respectively. Competitive performance evidenced in respect to research article publications among IIT researchers/faculties during the period of study..

8) It is observed that apart from research performance in Engineering, IITs also playing a leading role in the distinct branches of Science like Physics, Chemistry, Materials Science etc. 4 IITs other than IIT Kanpur contributed highest number of articles in engineering

individually in the top five productive research areas during last 50 years. IIT Madras contributed highest research publications in Engineering (7906) among all institutions followed by IIT Kharagpur (7834), IIT Delhi (7329), IIT Bombay (5843). Subsequent leading research areas of IIT Kharagpur, IIT Bombay, IIT Madras and IIT Delhi are Materials Science (5420), Chemistry (5148), Chemistry 5089) and Physics (4163) respectively. For IIT Kanpur, top five productive research areas started with Chemistry (5029 – 25.199% of TP) followed by engineering (4877).

7. Conclusion

IITs follow own statement of vision, mission, and core values, but all share a common theme where quality academic as well as research activities at par with the international standard found to be the hall mark of the IIT system. A dynamic progress of 5 older IITs as evident from the retrieved information from Web of Science on the publication rate of each five older IITs during last 50 years (1970-2019) with block year wise performance depicts a competitive growth in research productivity among the institutions. Among the 5 IITs, IIT Kharagpur published maximum number of research articles during the time span of 50 years but while counting the productivity for the blocks of every five years, different IITs achieved highest ranking in different block years. The citation profile, collaboration with national and international institutions as well countries, prolific authorship and progressive subject areas of research of each IIT with top five ranking discloses the competitive performance of individual institution.

8. References

1) Jeevan, V K J and Gupta, B M, A scientometric analysis of research output from Indian Institute of Technology, Kharagpur, Scientometrics, 53(1) (2002) 165-168.
2) Wani, Z A, Pandit, M T and Majeed, N, Research Productivity of Indian Institute of Technology, International Journal of Library and Information Science 5(7) (2013) 216-224.
3) Pratap, G, Benchmarking research performance of the IITs using Web of Science and Scopus bibliometric databases, Current Science, 105(8)(2013) 1134-1138.
4) Chaurasia, N K and Chavan, S B, Research output of Indian Institute of Technology Delhi (IIT Delhi) during 2001-2010 : a bibliometric analysis, International Journal of Information Dissemination and Technology 4(2) (2014) 141-147.
5) Hasan, N and Singh, M, Research output of Indian Institutes of Technology (IITs) : A scientometric study, Qualitative and Quantitative Methods in Libraries (QQML), 4 (2015), 293-305.
6) Arif,T, Analyzing Research Productivity of Indian Institutes of Technology, Communications on Applied Electronics, 1(8) (2015) 8-11.
7) Hadimani, N, Mulla, K R and Senthil Kumar, N, A Bibliometric Analysis of Research Publications of Indian Institute of Science Education and Research, Thiruvananthapuram, Journal of Advancements in Library Sciences, 2(1) (2015) 28-35.
8) Bid , S, Indian Institute of Technology, Kharagpur: A Scientometric study of Research Output, SSARSC International Journal of Library Information Network and Knowledge, 1(1) (2016)1-15.

9) Mohanty, B and Jena, P, Scientometric Analysis into Research Output of IIT Bombay in the field of Engineering during 2006-2016, International Journal of Information, Library & Society, 8(1)(2019)28-35.
10) Kumar, A, Singh, M and Chaman, R, Measuring the Research Output of Indian Institute of Technology (IITs) with Special Reference to Web of Science (WoS) Database : A Bibliometric Approach, Library Philosophy and Practice (e-journal), (2018) 1-13.
11) WoS (Web of Science), Available at <https://webofknowledge.com> Clarivate Analysis – retrieved on 15.09.2020.