

## COLLABORATION PATTERN IN THE RESEARCH OUTPUT OF NATIONAL INSTITUTES OF TECHNOLOGY IN INDIA DURING 1999 - 2018

*Iranna M. Shettar  
Gururaj S. Hadagali*

**Mr. Iranna M. Shettar**  
Assistant Librarian, Central  
Library,  
National Institute of  
Technology Karnataka  
Surathkal,  
Mangaluru – 575 025,  
KARNATAKA, INDIA  
Email: imshettar@gmail.com  
ORCID: 0000-0002-6790-2530  
**Corresponding Author**

**Dr. Gururaj S. Hadagali**  
Associate Professor,  
Department of Library and  
Information Science,  
Karnatak University, Dharwad  
– 580 003, KARNATAKA,  
INDIA  
Email:  
gururajhadagali123@gmail.com  
ORCID: 0000-0003-1372-4721

This study analyses the collaboration pattern in the Research Output of National Institutes of Technology in India for the period of twenty years (1999-2018) using the Web of Science citation database. The parameters used in the study are: Degree of Collaboration (DC), Collaboration Coefficient (CC), Collaborative Index (CI), Modified Collaborative Coefficient (MCC), Intra and Inter NIT collaborated articles and growth patterns of domestic and international collaborative articles. The results of the study reveal that the Degree of Collaboration (DC) for the journal articles published by NITs between 1999 and 2018 varied from 0.88 to 0.98. The lowest CI was recorded in the year 2000 (2.66), and the highest CI was recorded for the year 2016 (3.62). The Collaborative Coefficient (CC) ranges between 0.538 and 0.637, with an average rate of 0.626. Out of 16,049 (41.69%) journal articles, 1125 (2.92%) are single-authored, and 14,924 (38.77%) are intra and inter-NIT collaborated journal articles with two or more authors affiliated only with one or more NITs. Internationally collaborative journal articles achieved the highest ACPP with 18.42, followed by 13.39 ACPP by domestic collaborated journal articles, 12.48 ACPP by locally (NIT only) collaborated journal articles and the least ACPP of 2.52 by no collaborated journal articles.

**Keywords:** Research Collaboration, Collaboration Pattern, National Institutes of Technology, India, Research Output, Web of Science, Degree of Collaboration, Collaborative Index, Collaborative Coefficient, Inter-NIT Collaboration

### INTRODUCTION

Knowledge sharing and collaboration among the individuals, institutes and countries, especially in research always leads to a better society for mankind. Nowadays, collaboration in research is over emphasized with the development of Information and Communication Technology (ICT) and advancements in science. Collaboration helps researchers understand the research problem from various aspects and angles due to the geographical variations. At the same time, it encourages the research community in information sharing, transfer of technology and global solution to the local

problem. Katz and Martin (1997) defined research collaborations as the working together of researchers to achieve the common goal of producing new scientific knowledge. Although research collaboration takes place between two or more individual authors, but it helps to evaluate the research contribution and collaboration pattern of the institutions and countries. Keeping in view this in mind, the authors have tried to determine the extent of collaboration in National Institutes of Technology, India's premier institutions in the field of Engineering and Technology.

The National Institutes of Technology (NITs) were established initially as the Regional Engineering Colleges (RECs) during the second five-year plan to provide the basic engineering education across Indian states. However, in the year 2002, these colleges were promoted to the status of the deemed university to promote the research in the field of Engineering and Technology. Later in the year, 2007 twenty-one deemed universities were promoted to the status of 'Institute of National Importance' through an Act of Parliament. Subsequently, ten more NITs were established in 2010 and one in the year 2015. With the status of institutes of national importance, NITs were supported with the higher research funding and establishment of research facilities. This resulted in increased research activities and collaborations with the national and international institutes. These activities helped NITs to increase their visibility and status along with the number of research publications. Thus, the current study analyses the collaboration pattern in the Research output of National

Institutes of Technology between 1999 and 2018 (Council of NITs).

## **REVIEW OF RELATED LITERATURE**

Many authors have conducted studies on the collaboration, especially in the Technical Institutions in India contributing their significant share in the research publications in the field of Engineering Science and Technology. Collaboration helps to increase the visibility and reputation of an individual author, institution and the country.

Vijayakumar (2017) conducted a study to evaluate the collaborative research trends of the Indian Institutes of Technology. The author examines 14,879 bibliographic records from the Web of Science database published between 1994 and 2004. The study recorded 0.93 Degree of Collaboration for the whole period of study and noticed an increasing trend from one phase to another, which is a common trend in collaborative research in the field of Science and Technology. Banshal et al. (2017) analyse the research performance of Indian Institutes of Technology established before 2012 by analysing 32,308 records extracted from the WoS published between 1990 and 2014. The study found that 8,807 (27.26%) publications have international collaborations. Among them, IIT Bombay (1470) has the maximum number of internationally collaborative papers. The USA was the most preferred collaborative country. The authors also observed that new IITs were not far behind in international collaboration. Singh and Gupta (2010) analyse Indian engineering research during

1999-2008 as indexed in Scopus database. India has published 48,239 papers and 3,378 (14.21%) publications are internationally collaborated. The USA (43.11%) was India's major collaborating country with the largest share. 8 IITs and 4 NITs appeared in the top 30 Indian Institutions list.

Bala and Kumari (2013) analyse the research performance of 20 NITs using 8,841 bibliographic records indexed in Scopus database between 2001 and 2010. 905 (10.24 %) publications have international collaboration which received 1,189 (1.31 %) citations with 1.31 ACPP. Among the individual NIT, NIT Trichy has the highest i.e. 223 international collaborated publications with the maximum 24.64% share, followed by NIT Karnataka, Surathkal (125, 13.81%). The USA (22.76%) was the most preferred collaborative country, followed by Malasiya (13.48 %). Tamilselvan and Sivakumar (2013) analyse the literature published by NITs between 2001 and 2010. A total of 8,372 records were analysed and found 0.94 Degree of Collaboration. The Lotka's generalised inverse square law holds good to the literature published by NIT's during the period of study with critical value of 0.24. Banshal et al. (2018) assess the research performance of 31 NITs based on the WoS which indexed 14,385 publications during the period 2005-2016. 2,185 (15.19 %) publications were internationally collaborated papers. NIT Trichy has the highest international collaboration amongst the NITs.

Hasan and Singh (2015) evaluate the research performance of Indian Institutes of Technology especially top 5 most performing IITs based on the number publications indexed in WoS (2009-

2013). Together, these five IITs published 20,046 research papers. IIT Madras (138) has the maximum number of collaborations. All the five IITs together have 9,072 (45.71%) international collaborated publications with 96 countries and 3,915 institutional collaboration produced 78.94% overall publications. Shettar and Hadagali (2020) assess the research productivity of NITs as indexed in WoS for the period from 2009 to 2018. The study found that NIT Calicut has the highest Degree of Collaboration (0.9896) and NIT Raipur recorded the lowest Degree of Collaboration (0.9439). NITK Rourkela (5077) has the highest collaborated papers and the lowest by NIT Puducherry (60). However, NIT Trichy has the highest 695 international collaborated publications. Overall, collaborated papers received 6.53 average citations per collaborated paper and overall international collaborated publications received 10.3 average citations per paper during the study.

Pradhan and Sahu (2018) analyse the publication performance of five old Indian Institutes of Technology using Scopus database during 2007-2016. The study recorded 0.96 average Degree of Collaboration across the IITs, which shows that multi-author publications drastically dominate over the single author publications. IIT Kharagpur recorded the highest Degree of Collaboration with 0.97. IIT Bombay had nearly 64.74% publications which were internationally collaborated and overall IIT publications were collaborated with more than 50 countries. Siddaiah et al. (2016) investigate the research performance of eight newly established Indian Institutes of Technology (established after

2008). The authors analysed 3,656 research publications retrieved from the Scopus database published between 2010 and 2014. The study found that 1,301 (35.59%) publications were of national collaboration. IIT Hyderabad has the maximum number of national collaborated publications (295) and international collaborations (229). The number of international collaborative publications by the eight new IITs was 1036 (28.34%) publications. Whereas, IIT Mandi (41.60%) has the maximum share of its publications through international collaborations.

India has 115 Centrally Funded Technical Institutes (CFTIs). Among these, National Institutes of Technology (NITs) treated next to the Indian Institutes of Technology (IITs) in all respects. However, one can find a very few studies in which collaboration has used as one of the indicators in their studies. No study has been done on the collaboration amongst IIT or NITs. Hence, the present study deals with the collaboration pattern in the research output of NITs considering NITs as one unit.

### **OBJECTIVES OF THE STUDY**

The major objective of this study is to analyse the collaboration pattern in the research output of the National Institutes of Technology (NITs) in India for a period of twenty years from 1999 to 2018. The specific objectives of the study are to:

1. study the institution and year wise distribution of Journal articles and citations of National Institutes of Technology;
2. determine the values of Degree of Collaboration (DC), Collaboration

Coefficient (CC) and Collaborative Index (CI) of National Institutes of Technology in India;

3. analyse the intra and inter NIT collaborated articles; and
4. know the growth patterns of domestic and international collaborative articles.

### **METHODS AND MATERIALS**

The current study analyses the research publications of National Institutes of Technology especially the journal articles indexed in the Web of Science database published between 1999 and 2018. All the thirty-one NITs were considered for the study and together published 38,497 journal articles. These bibliographic records were retrieved in plain text format, further the extracted data was then analysed using HistCite and Ms-Excel applications.

### **ANALYSIS AND INTERPRETATION OF DATA**

#### **Distribution of Journal Articles in NITs**

The table 1 presents the institute wise distribution of publications and citations. The total publications output comprises of 39,531 journal articles published in 4310 journals in twenty years' period between 1999 and 2018. NIT Rourkela has the highest number of journal articles during the period with 4888 articles, followed by NIT Trichy (4627) and NITK Surathkal (3151). According to the number of citations received for these journal articles, NIT Rourkela lead the table with 77,754 citations, followed by NIT Trichy (76,400 citations) and NITK Surathkal (36165 citations). According to the average citations per paper (ACPP), MANIT

Bhopal lead the table with the maximum 17.92 ACP, followed by NIT Trichy (16.51) and NIT Rourkela (15.91). According to h-index, NIT Trichy lead the table with the highest h-index of

95, followed by NIT Rourkela (89) and MANIT Bhopal and NIT Durgapur (71 each). NIT Rourkela and NIT Trichy are the most productive institutes among the NITs.

**Table 1: Institute wise distribution of Journal Articles**

| Name of the Institute | TP    | TC     | %TP    | %TC    | ACPP  | h-index |
|-----------------------|-------|--------|--------|--------|-------|---------|
| NIT Rourkela          | 4888  | 77754  | 12.36  | 14.43  | 15.91 | 89      |
| NIT Trichy            | 4627  | 76400  | 11.70  | 14.18  | 16.51 | 95      |
| NITK Surathkal        | 3151  | 36165  | 7.97   | 6.71   | 11.48 | 67      |
| NIT Durgapur          | 2461  | 35170  | 6.23   | 6.53   | 14.29 | 71      |
| NIT Warangal          | 2295  | 27999  | 5.81   | 5.20   | 12.20 | 61      |
| SVNIT Surat           | 2185  | 34054  | 5.53   | 6.32   | 15.59 | 69      |
| NIT Kurukshetra       | 2057  | 26344  | 5.20   | 4.89   | 12.81 | 63      |
| MNNIT Allahabad       | 2022  | 30269  | 5.11   | 5.62   | 14.97 | 65      |
| NIT Calicut           | 1859  | 25529  | 4.70   | 4.74   | 13.73 | 63      |
| VNIT Nagpur           | 1843  | 21996  | 4.66   | 4.08   | 11.93 | 56      |
| MNIT Jaipur           | 1770  | 21970  | 4.48   | 4.08   | 12.41 | 57      |
| BRANIT Jalandhar      | 1649  | 18961  | 4.17   | 3.52   | 11.50 | 49      |
| NIT Hamirpur          | 1522  | 23151  | 3.85   | 4.30   | 15.21 | 64      |
| MANIT Bhopal          | 1337  | 23955  | 3.38   | 4.45   | 17.92 | 71      |
| NIT Silchar           | 1199  | 17971  | 3.03   | 3.34   | 14.99 | 53      |
| NIT Raipur            | 973   | 8652   | 2.46   | 1.61   | 8.89  | 36      |
| NIT Agartala          | 938   | 8026   | 2.37   | 1.49   | 8.56  | 35      |
| NIT Jamshedpur        | 629   | 7152   | 1.59   | 1.33   | 11.37 | 37      |
| NIT Srinagar          | 503   | 3965   | 1.27   | 0.74   | 7.88  | 26      |
| NIT Patna             | 402   | 3007   | 1.02   | 0.56   | 7.48  | 23      |
| NIT Meghalaya         | 283   | 2786   | 0.72   | 0.52   | 9.84  | 22      |
| NIT Manipur           | 184   | 1057   | 0.47   | 0.20   | 5.74  | 17      |
| NIT Delhi             | 141   | 1551   | 0.36   | 0.29   | 11.00 | 20      |
| NIT Arunachal Pradesh | 127   | 632    | 0.32   | 0.12   | 4.98  | 13      |
| NIT Puducherry        | 107   | 886    | 0.27   | 0.16   | 8.28  | 16      |
| NIT Goa               | 101   | 1185   | 0.26   | 0.22   | 11.73 | 18      |
| NIT Nagaland          | 81    | 597    | 0.20   | 0.11   | 7.37  | 13      |
| NIT Uttarakhand       | 67    | 522    | 0.17   | 0.10   | 7.79  | 14      |
| NIT Sikkim            | 62    | 356    | 0.16   | 0.07   | 5.74  | 10      |
| NIT Mizoram           | 53    | 509    | 0.13   | 0.09   | 9.60  | 14      |
| NIT Andhra Pradesh    | 15    | 176    | 0.04   | 0.03   | 11.73 | 7       |
| Total                 | 39531 | 538747 | 100.00 | 100.00 | 13.63 | 167     |

TP= Total Publications (Journal Articles), TC= Total Citations, ACP= Average Citations per Papers

### Year wise distribution of Journal Articles and Citations

The table 2 depicts the year wise distribution of the total research output of all NITs together, avoiding the duplications with regard to collaborative publications within few NITs. Together, all 31 NITs published 38,497 journal articles which is equivalent to 59.26% of the overall publication output of these NIT's, including other document types like Conference papers, Book Chapters, letters etc. The highest number of publications were recorded for the year 2018 (6638 journal articles published), followed by 2017 (5691) and 2016 (4805)

respectively. However, journal articles published in the year 2016 has received the highest number of citations i.e. 55,019, followed by 2015 (51,089) and 2014 (49,291). The highest average citations per paper (ACPP) was recorded in the year 1999 with 24.94 ACPP, followed by 2003 (24.21) and 2005 (23.44). The Annual Growth Rate (AGR) was calculated based on the formula given by Gracio et al. (2013). The highest AGR was recorded for the year 2008 with 47.47 AGR, followed by 2009 (2009) and 2004 (34.07). According to Choi et al. (2011), Compound Annual Growth Rate (CAGR) is a standard for measuring the growth of journal articles for the

**Table 2: Year wise distribution of Journal Articles and Citations in NITs**

| Year  | TP     | TC       | %TP    | %TC    | ACPP  | AGR   | CAGR |
|-------|--------|----------|--------|--------|-------|-------|------|
| 1999  | 179    | 4464     | 0.46   | 0.85   | 24.94 | -     | 19.8 |
| 2000  | 187    | 2914     | 0.49   | 0.55   | 15.58 | 4.47  |      |
| 2001  | 187    | 3711     | 0.49   | 0.71   | 19.84 | 0.00  |      |
| 2002  | 206    | 3182     | 0.54   | 0.61   | 15.45 | 10.16 |      |
| 2003  | 273    | 6608     | 0.71   | 1.26   | 24.21 | 32.52 |      |
| 2004  | 366    | 7882     | 0.95   | 1.50   | 21.54 | 34.07 |      |
| 2005  | 436    | 10219    | 1.13   | 1.94   | 23.44 | 19.13 |      |
| 2006  | 541    | 11945    | 1.41   | 2.27   | 22.08 | 24.08 |      |
| 2007  | 691    | 16137    | 1.79   | 3.07   | 23.35 | 27.73 |      |
| 2008  | 1019   | 22134    | 2.65   | 4.21   | 21.72 | 47.47 |      |
| 2009  | 1422   | 31310    | 3.69   | 5.96   | 22.02 | 39.55 |      |
| 2010  | 1645   | 36555    | 4.27   | 6.96   | 22.22 | 15.68 |      |
| 2011  | 2031   | 36427    | 5.28   | 6.93   | 17.94 | 23.47 |      |
| 2012  | 2260   | 39347    | 5.87   | 7.49   | 17.41 | 11.28 |      |
| 2013  | 2821   | 48463    | 7.33   | 9.22   | 17.18 | 24.82 |      |
| 2014  | 3294   | 49291    | 8.56   | 9.38   | 14.96 | 16.77 |      |
| 2015  | 3805   | 51089    | 9.88   | 9.72   | 13.43 | 15.51 |      |
| 2016  | 4805   | 55019    | 12.48  | 10.47  | 11.45 | 26.28 |      |
| 2017  | 5691   | 48062    | 14.78  | 9.15   | 8.45  | 18.44 |      |
| 2018  | 6638   | 40748    | 17.24  | 7.75   | 6.14  | 16.64 |      |
| Total | 38,497 | 5,25,507 | 100.00 | 100.00 | 13.65 |       |      |

### Degree of Collaboration (DC) in NITs

The Degree of Collaboration (DC) is the ratio of number of collaborative research papers to the total number of research papers during certain period of time. The DC was calculated using the mathematical formula proposed by Subramanyam (1983). The table 3 reveals that the value of the Degree of Collaboration (DC) for the journal articles published by NITs between 1999 and 2018 varied from 0.88 to 0.98. The

lowest DC i.e. 0.88 was recorded in the year 2000 and the highest DC i.e. 0.98 was recorded every year after 2014. It was observed that the Degree of Collaboration (DC) was progressively increased over the years and the reason could be the increase in the collaborative efforts among the researchers, due to the status of deemed university in 2002 and status of institute of national importance granted by the MHRD to promote research in NITs.

**Table 3: Degree of Collaboration (DC) in NITs**

| Year  | Single authored (Ns) | Percentage (%) | Multi authored (Nm) | Percentage (%) | Total (Ns + Nm) | Degree of Collaboration |
|-------|----------------------|----------------|---------------------|----------------|-----------------|-------------------------|
| 1999  | 19                   | 10.61          | 160                 | 89.39          | 179             | 0.89                    |
| 2000  | 23                   | 12.3           | 164                 | 87.7           | 187             | 0.88                    |
| 2001  | 18                   | 9.63           | 169                 | 90.37          | 187             | 0.9                     |
| 2002  | 14                   | 6.8            | 192                 | 93.2           | 206             | 0.93                    |
| 2003  | 23                   | 8.42           | 250                 | 91.58          | 273             | 0.92                    |
| 2004  | 25                   | 6.83           | 341                 | 93.17          | 366             | 0.93                    |
| 2005  | 27                   | 6.19           | 409                 | 93.81          | 436             | 0.94                    |
| 2006  | 45                   | 8.32           | 496                 | 91.68          | 541             | 0.92                    |
| 2007  | 46                   | 6.66           | 645                 | 93.34          | 691             | 0.93                    |
| 2008  | 54                   | 5.3            | 965                 | 94.7           | 1019            | 0.95                    |
| 2009  | 60                   | 4.22           | 1362                | 95.78          | 1422            | 0.96                    |
| 2010  | 75                   | 4.56           | 1570                | 95.44          | 1645            | 0.95                    |
| 2011  | 83                   | 4.09           | 1948                | 95.91          | 2031            | 0.96                    |
| 2012  | 72                   | 3.19           | 2188                | 96.81          | 2260            | 0.97                    |
| 2013  | 86                   | 3.05           | 2735                | 96.95          | 2821            | 0.97                    |
| 2014  | 65                   | 1.97           | 3229                | 98.03          | 3294            | 0.98                    |
| 2015  | 64                   | 1.68           | 3741                | 98.32          | 3805            | 0.98                    |
| 2016  | 91                   | 1.89           | 4714                | 98.11          | 4805            | 0.98                    |
| 2017  | 94                   | 1.65           | 5597                | 98.35          | 5691            | 0.98                    |
| 2018  | 141                  | 2.12           | 6497                | 97.88          | 6638            | 0.98                    |
| Total | 1125                 | 2.92           | 37372               | 97.08          | 38497           | 0.97                    |

### Collaboration Coefficient & Collaborative Index of NITs in India

The study shows that multi-authored publications dominate over single-authored publications. The also study shows that NITs have 2.92% single authored articles compared to 97.08% multi-authored publications. According to the Clarivate Analytics Report, on an average three authors contribute for a single publication. However, NITs have more number of two authored journal articles (33.55%), followed by three

authored journal articles (31.42%). The table 4 also depicts the year-wise Collaborative Index, Collaboration Coefficient and Modified Collaboration Coefficient of journal articles published by NITs during the period.

The lowest CI (as proposed by Lawani (1980)) was recorded in the year 2000 (2.66) and the highest number of CI was recorded for the year 2016 (3.62). The average Collaborative Index calculated for the whole period of study was 3.34 which means that the average authors per journal

**Table 4: Collaboration Coefficient and Collaborative Index in NITs in India**

| Year  | Single Author Papers | Two Authors Papers | Three Authors Papers | Four Authors Papers | Five & Above Authors Papers | Total Papers | Total Authors of Multi Authored Papers | No of Total Authors | CC    | CI   | MCC   |
|-------|----------------------|--------------------|----------------------|---------------------|-----------------------------|--------------|----------------------------------------|---------------------|-------|------|-------|
| 1999  | 19                   | 68                 | 62                   | 15                  | 15                          | 179          | 468                                    | 487                 | 0.551 | 2.72 | 0.554 |
| 2000  | 23                   | 71                 | 64                   | 14                  | 15                          | 187          | 475                                    | 498                 | 0.538 | 2.66 | 0.541 |
| 2001  | 18                   | 67                 | 61                   | 23                  | 18                          | 187          | 515                                    | 533                 | 0.566 | 2.85 | 0.569 |
| 2002  | 14                   | 68                 | 83                   | 22                  | 19                          | 206          | 585                                    | 599                 | 0.588 | 2.91 | 0.590 |
| 2003  | 23                   | 97                 | 97                   | 34                  | 22                          | 273          | 753                                    | 776                 | 0.572 | 2.84 | 0.575 |
| 2004  | 25                   | 125                | 139                  | 52                  | 25                          | 366          | 1022                                   | 1047                | 0.585 | 2.86 | 0.587 |
| 2005  | 27                   | 162                | 144                  | 65                  | 38                          | 436          | 1231                                   | 1258                | 0.588 | 2.89 | 0.589 |
| 2006  | 45                   | 191                | 179                  | 80                  | 46                          | 541          | 1497                                   | 1542                | 0.576 | 2.85 | 0.577 |
| 2007  | 46                   | 214                | 266                  | 90                  | 75                          | 691          | 1991                                   | 2037                | 0.596 | 2.95 | 0.597 |
| 2008  | 54                   | 341                | 360                  | 162                 | 102                         | 1019         | 3034                                   | 3088                | 0.602 | 3.03 | 0.603 |
| 2009  | 60                   | 467                | 479                  | 232                 | 184                         | 1422         | 4351                                   | 4411                | 0.615 | 3.1  | 0.615 |
| 2010  | 75                   | 546                | 533                  | 243                 | 248                         | 1645         | 5074                                   | 5149                | 0.613 | 3.13 | 0.614 |
| 2011  | 83                   | 678                | 677                  | 313                 | 280                         | 2031         | 6256                                   | 6339                | 0.615 | 3.12 | 0.615 |
| 2012  | 72                   | 731                | 727                  | 396                 | 334                         | 2260         | 7246                                   | 7318                | 0.626 | 3.24 | 0.626 |
| 2013  | 86                   | 922                | 919                  | 503                 | 391                         | 2821         | 8953                                   | 9039                | 0.625 | 3.2  | 0.625 |
| 2014  | 65                   | 1132               | 1061                 | 596                 | 440                         | 3294         | 10517                                  | 10582               | 0.629 | 3.21 | 0.629 |
| 2015  | 64                   | 1310               | 1149                 | 681                 | 601                         | 3805         | 13065                                  | 13129               | 0.634 | 3.45 | 0.634 |
| 2016  | 91                   | 1575               | 1480                 | 811                 | 848                         | 4805         | 17286                                  | 17377               | 0.637 | 3.62 | 0.637 |
| 2017  | 94                   | 1934               | 1692                 | 975                 | 996                         | 5691         | 19768                                  | 19862               | 0.637 | 3.49 | 0.637 |
| 2018  | 141                  | 2217               | 1923                 | 1125                | 1232                        | 6638         | 23308                                  | 23449               | 0.636 | 3.53 | 0.636 |
| Total | 1125                 | 12916              | 12095                | 6432                | 5929                        | 38497        | 127395                                 | 128520              | 0.626 | 3.34 | 0.626 |

article for the period of study was 3.34 authors, which is equivalent to the global benchmark of most frequent number of authors on an article as defined by Clarivate Analytics. According to Ajiferuke et al. (1988) Collaboration Coefficient (CC) lies between 0 and 1, with 0 corresponding to single authored papers. If the value of CC is more than 0.5 means which tends to strong collaboration rate among the authors. The CC ranges between 0.538 and 0.637 with an average rate of 0.626. As the mean value of the CC for the period of study is more than 0.5, the collaboration rate among the authors is found better. Modified Collaborative Coefficient (MCC) was proposed by Savanur and Srikanth (2010) unlike CC, which remains strictly less than 1 for finite authors. MCC smoothly tends to 1 as the Degree of Collaboration becomes maximum. The table 4 shows that MCC ranges between 0.541 and 0.637 and mean MCC was 0.626. However, it is also observed from the study that no significant difference was observed between CC values and MCC values as multi-authored publications are dominating over the single authored papers.

### **Growth pattern of Intra and Inter NIT Collaboration articles**

The table 5 provides the year wise statistics for core NITs journal articles which are mostly by a single author or collaborated authors within NITs. A total of 16,049 (41.69%) journal articles are by the authors affiliated only to NITs. Among 16,049 (41.69%) journal articles, 1125 (2.92%) are single authored journal articles and 14,924 (38.77%) are intra and inter-NIT collaborated journal articles with two or more authors affiliated only with one or more NITs. The lowest single

authored journal articles were recorded during 2002 (14, 0.04) and the highest, i.e. 141 (0.37%) in the year 2018. These 1125 single authored journal articles received 13,236 (2.52%) citations with 11.77 average citations per paper (ACPP). The highest citations received for the journal articles published in the year 2006 with 1330 citations from 45 articles. However, the highest ACPP was recorded for the journal articles published in the year 2005 with 48 ACPP, whereas, 1296 citations received for the 27 journal articles. Over the period of twenty years, NITs' single authored journal articles raised with CAGR of 10.54.

Out of 14,924 collaborated journal articles within NIT, the highest i.e. 2911 (7.56%) journal articles were recorded in the year 2018 and the lowest, i.e. 61 journal articles were recorded in the year 1999. The NIT collaborated journal articles have received a total of 1,86,245 (35.44 %) citations with 12.48 ACPP. The highest citations were received for the journal articles i.e. 22,770 (4.33%) for 2004 articles and the highest ACPP i.e. 26.15 received for the journal articles published in the year 2005, where, 106 journal articles received 2772 citations. The NITs only collaborated journal articles increased from 61 in 1999 to 2911 in the year 2018 with CAGR of 21.32. It is noticed from the data that the NITs only collaborated journal articles increased at a faster rate than the single-authored NIT journal articles. Overall NITs only affiliated 16,049 (41.69%) journal articles have received 1,99,481 (37.96%) citations at 12.43 ACPP, which is lower than the overall ACPP (13.65). Hence, it is observed that NIT only journal articles have not

**Table 5: Growth pattern of Intra and Inter NIT Collaboration articles**

| Year  | No Collaboration |      |       |      |       | Within NIT Collaboration |       |        |       |       |
|-------|------------------|------|-------|------|-------|--------------------------|-------|--------|-------|-------|
|       | TP               | %    | TC    | %    | ACPP  | TP                       | %     | TC     | %     | ACPP  |
| 1999  | 19               | 0.05 | 141   | 0.03 | 7.42  | 61                       | 0.16  | 825    | 0.16  | 13.52 |
| 2000  | 23               | 0.06 | 142   | 0.03 | 6.17  | 62                       | 0.16  | 726    | 0.14  | 11.71 |
| 2001  | 18               | 0.05 | 154   | 0.03 | 8.56  | 63                       | 0.16  | 704    | 0.13  | 11.17 |
| 2002  | 14               | 0.04 | 67    | 0.01 | 4.79  | 77                       | 0.20  | 997    | 0.19  | 12.95 |
| 2003  | 23               | 0.06 | 854   | 0.16 | 37.13 | 83                       | 0.22  | 1092   | 0.21  | 13.16 |
| 2004  | 25               | 0.06 | 803   | 0.15 | 32.12 | 84                       | 0.22  | 1609   | 0.31  | 19.15 |
| 2005  | 27               | 0.07 | 1296  | 0.25 | 48    | 106                      | 0.28  | 2772   | 0.53  | 26.15 |
| 2006  | 45               | 0.12 | 1330  | 0.25 | 29.56 | 136                      | 0.35  | 3035   | 0.58  | 22.32 |
| 2007  | 46               | 0.12 | 1001  | 0.19 | 21.76 | 165                      | 0.43  | 4497   | 0.86  | 27.25 |
| 2008  | 54               | 0.14 | 770   | 0.15 | 14.26 | 281                      | 0.73  | 6903   | 1.31  | 24.57 |
| 2009  | 60               | 0.16 | 667   | 0.13 | 11.12 | 410                      | 1.07  | 8137   | 1.55  | 19.85 |
| 2010  | 75               | 0.19 | 1035  | 0.20 | 13.8  | 509                      | 1.32  | 11024  | 2.10  | 21.66 |
| 2011  | 83               | 0.22 | 694   | 0.13 | 8.36  | 684                      | 1.78  | 14392  | 2.74  | 21.04 |
| 2012  | 72               | 0.19 | 627   | 0.12 | 8.71  | 839                      | 2.18  | 13307  | 2.53  | 15.86 |
| 2013  | 86               | 0.22 | 763   | 0.15 | 8.87  | 1103                     | 2.87  | 17038  | 3.24  | 15.45 |
| 2014  | 65               | 0.17 | 631   | 0.12 | 9.71  | 1277                     | 3.32  | 18365  | 3.49  | 14.38 |
| 2015  | 64               | 0.17 | 348   | 0.07 | 5.44  | 1547                     | 4.02  | 21293  | 4.05  | 13.76 |
| 2016  | 91               | 0.24 | 1201  | 0.23 | 13.2  | 2004                     | 5.21  | 22770  | 4.33  | 11.36 |
| 2017  | 94               | 0.24 | 263   | 0.05 | 2.8   | 2522                     | 6.55  | 20478  | 3.90  | 8.12  |
| 2018  | 141              | 0.37 | 449   | 0.09 | 3.18  | 2911                     | 7.56  | 16281  | 3.10  | 5.59  |
| Total | 1125             | 2.92 | 13236 | 2.52 | 11.77 | 14924                    | 38.77 | 186245 | 35.44 | 12.48 |
| CAGR  | 10.54            |      |       |      |       | 21.32                    |       |        |       |       |

attracted good number of citations from the research community.

#### **Growth pattern of domestic and international collaborative articles**

The table 6 presents the data on the parameters related to the domestic and international collaborations for the journal articles published by the NITs during the period 1999-2018. The data indicate that the NITs have 17,388 domestically collaborated journal articles which increased from 81 in 1999 to 2631 in 2018 with the CAGR of 19.01. However, the lowest

numbers of journal articles were recorded in the year 2000 with only 77 domestically collaborated journal articles. These 17,388 domestically collaborated journal articles by NITs were 45.17% of the overall journal articles by NITs and received 2,32,844 citations, which is 44.31% of the overall citations received by all the journal articles published by NITs. The lowest citations received for the journal articles published in the year 2000 (1279, 0.24 %) and the highest citations were received for the journal articles published in the year 2014. Overall, 17,388

domestically collaborated journal articles received 2,32,844 citations with 13.39 ACPP.

The table 6 also shows that NITs have 5060 internationally collaborated journal articles which increased at 21.97 CAGR from 18 in 1999 and 955 in 2018. However, the lowest internationally collaborated journal articles were published in the year 2001 with only 15 internationally collaborated journal articles. The 5060 (13.14%) internationally collaborated journal articles received 93,182 (17.73 %) citations. The highest i.e. 10,473 citations were received journal articles

published in the year 2013 and the lowest i.e. 245 citations received for the journal articles published during 1999. The highest average citation per paper (ACPP) was recorded for the journal articles published in the year 2001 with 60.6 ACPP and the lowest for the year 2018 with 9.97 ACPP. 5060 internationally collaborated journal articles received 93,182 citations with 18.42 ACPP. From the data it is observed that although number of journal articles was high in domestically collaborated journal articles but the rate of CAGR and ACPP stands high for

**Table 6: Growth pattern of domestic and international collaborative articles**

| Year  | Domestic Collaboration |       |        |       |       | International Collaboration |       |       |       |       |
|-------|------------------------|-------|--------|-------|-------|-----------------------------|-------|-------|-------|-------|
|       | TP                     | %     | TC     | %     | ACPP  | TP                          | %     | TC    | %     | ACPP  |
| 1999  | 81                     | 0.21  | 3253   | 0.62  | 40.16 | 18                          | 0.05  | 245   | 0.05  | 13.61 |
| 2000  | 77                     | 0.20  | 1279   | 0.24  | 16.61 | 25                          | 0.06  | 767   | 0.15  | 30.68 |
| 2001  | 91                     | 0.24  | 1944   | 0.37  | 21.36 | 15                          | 0.04  | 909   | 0.17  | 60.6  |
| 2002  | 98                     | 0.25  | 1865   | 0.35  | 19.03 | 17                          | 0.04  | 253   | 0.05  | 14.88 |
| 2003  | 141                    | 0.37  | 3604   | 0.69  | 25.56 | 26                          | 0.07  | 1058  | 0.20  | 40.69 |
| 2004  | 213                    | 0.55  | 4258   | 0.81  | 19.99 | 44                          | 0.11  | 1212  | 0.23  | 27.55 |
| 2005  | 261                    | 0.68  | 5036   | 0.96  | 19.3  | 42                          | 0.11  | 1115  | 0.21  | 26.55 |
| 2006  | 311                    | 0.81  | 6627   | 1.26  | 21.31 | 49                          | 0.13  | 953   | 0.18  | 19.45 |
| 2007  | 406                    | 1.05  | 9016   | 1.72  | 22.21 | 74                          | 0.19  | 1623  | 0.31  | 21.93 |
| 2008  | 577                    | 1.50  | 11163  | 2.12  | 19.35 | 107                         | 0.28  | 3298  | 0.63  | 30.82 |
| 2009  | 756                    | 1.96  | 17018  | 3.24  | 22.51 | 196                         | 0.51  | 5488  | 1.04  | 28    |
| 2010  | 850                    | 2.21  | 16680  | 3.17  | 19.62 | 211                         | 0.55  | 7816  | 1.49  | 37.04 |
| 2011  | 1003                   | 2.61  | 16226  | 3.09  | 16.18 | 261                         | 0.68  | 5115  | 0.97  | 19.6  |
| 2012  | 1036                   | 2.69  | 17988  | 3.42  | 17.36 | 313                         | 0.81  | 7425  | 1.41  | 23.72 |
| 2013  | 1246                   | 3.24  | 20189  | 3.84  | 16.2  | 386                         | 1.00  | 10473 | 1.99  | 27.13 |
| 2014  | 1511                   | 3.92  | 21934  | 4.17  | 14.52 | 441                         | 1.15  | 8361  | 1.59  | 18.96 |
| 2015  | 1700                   | 4.42  | 20376  | 3.88  | 11.99 | 494                         | 1.28  | 9072  | 1.73  | 18.36 |
| 2016  | 2096                   | 5.44  | 21306  | 4.05  | 10.17 | 614                         | 1.59  | 9742  | 1.85  | 15.87 |
| 2017  | 2303                   | 5.98  | 18581  | 3.54  | 8.07  | 772                         | 2.01  | 8740  | 1.66  | 11.32 |
| 2018  | 2631                   | 6.83  | 14501  | 2.76  | 5.51  | 955                         | 2.48  | 9517  | 1.81  | 9.97  |
| Total | 17388                  | 45.17 | 232844 | 44.31 | 13.39 | 5060                        | 13.14 | 93182 | 17.73 | 18.42 |
| CAGR  | 19.01                  |       |        |       |       | 21.97                       |       |       |       |       |

TP: Total Papers, TC= Total Citations, ACPP= Average Citations Per Paper

international collaborated journal articles. The value of CAGR shows that the growth rate of internationally collaborated journal articles is faster than the domestic collaboration. As per the analysis, the international collaborated journal articles earned more ACPP than the domestic collaborated journal articles. The study proves the statement that “One additional country on an article has a greater benefit than one additional

author” defined in ISI Global Research Report by Clarivate Analytics (Adams et al., 2019).

### **Pattern of collaboration with Domestic and international collaborative index**

The table 7 indicates that number of collaborative journal articles (97.08%) dominate over the single authored journal articles (2.92%). Among the collaborative journal articles, the

**Table 7: Pattern of collaboration with Domestic and International collaborative index**

| <b>Year</b> | <b>DCP</b> | <b>ICP</b> | <b>LCP (NIT)</b> | <b>TCP</b> | <b>NCP</b> | <b>TNP</b> | <b>DCI</b> | <b>ICI</b> |
|-------------|------------|------------|------------------|------------|------------|------------|------------|------------|
| 1999        | 81         | 18         | 61               | 160        | 19         | 179        | 100        | 77         |
| 2000        | 77         | 25         | 62               | 164        | 23         | 187        | 91         | 102        |
| 2001        | 91         | 15         | 63               | 169        | 18         | 187        | 108        | 61         |
| 2002        | 98         | 17         | 77               | 192        | 14         | 206        | 105        | 63         |
| 2003        | 141        | 26         | 83               | 250        | 23         | 273        | 114        | 72         |
| 2004        | 213        | 44         | 84               | 341        | 25         | 366        | 129        | 91         |
| 2005        | 261        | 42         | 106              | 409        | 27         | 436        | 133        | 73         |
| 2006        | 311        | 49         | 136              | 496        | 45         | 541        | 127        | 69         |
| 2007        | 406        | 74         | 165              | 645        | 46         | 691        | 130        | 81         |
| 2008        | 577        | 107        | 281              | 965        | 54         | 1019       | 125        | 80         |
| 2009        | 756        | 196        | 410              | 1362       | 60         | 1422       | 118        | 105        |
| 2010        | 850        | 211        | 509              | 1570       | 75         | 1645       | 114        | 98         |
| 2011        | 1003       | 261        | 684              | 1948       | 83         | 2031       | 109        | 98         |
| 2012        | 1036       | 313        | 839              | 2188       | 72         | 2260       | 101        | 105        |
| 2013        | 1246       | 386        | 1103             | 2735       | 86         | 2821       | 98         | 104        |
| 2014        | 1511       | 441        | 1277             | 3229       | 65         | 3294       | 102        | 102        |
| 2015        | 1700       | 494        | 1547             | 3741       | 64         | 3805       | 99         | 99         |
| 2016        | 2096       | 614        | 2004             | 4714       | 91         | 4805       | 97         | 97         |
| 2017        | 2303       | 772        | 2522             | 5597       | 94         | 5691       | 90         | 103        |
| 2018        | 2631       | 955        | 2911             | 6497       | 141        | 6638       | 88         | 109        |
| Total       | 17388      | 5060       | 14924            | 37372      | 1125       | 38497      | -          | -          |
| %           | 45.17%     | 13.14%     | 38.77%           | 97.08%     | 2.92%      | 100%       | -          | -          |
| ACPP        | 13.39      | 18.42      | 12.48            | -          | 2.52       | -          | -          | -          |

DCP: Domestic Collaborative Papers, ICP: International Collaborative Papers, LCP: Local Collaborative Papers within NITs, TCP: Total Collaborative Papers, NCP: No Collaborative Papers, TNP: Total Number of Papers, DCI: Domestic Collaborative Index, ICI: International Collaborative Index

domestic collaborative journal articles dominate with the highest i.e. 45.17%, followed by local collaborative journal articles (intra and inter NIT collaboration) with 38.77% of share than the least share by the internationally collaborative journal articles with 13.14% of the total journal articles published by NITs. But, internationally collaborative journal articles achieved the highest ACPP with 18.42, followed by 13.39 ACPP by domestic collaborated journal articles, 12.48 ACPP by locally (NIT only) collaborated journal articles and the least ACPP of 2.52 by no collaborated journal articles.

To examine the shift in pattern of collaboration, the Domestic Collaborative Index (DCI) and International Collaborative Index (ICI) suggested by Garg and Padhi (2001) were used. The value of DCI or ICI = 100 suggests that a country's collaborative effort corresponds to the world average. DCI or ICI > 100 indicates that the collaboration is higher than the world average. Out of twenty years except 6 years (2000, 2013, 2015-18) the values of DCI were more than 100, and for 7 years the ICI value was more than 100. Hence, the data indicates the domination of domestic collaborations over the international collaboration and higher values of DCI for different years imply that the proportion of journal articles published by NITs in domestic collaboration is more than the world's average.

## CONCLUSION

This study indicates the yearly rate of growth of journal articles in 20 years is 19.8 %. Although NITs were promoted to the deemed to be university status in 2002 from college status to the institute of national importance in 2007, but

the Compound Annual Growth Rate (CAGR) i.e. 19.8 is very productive growth in Engineering and Technology discipline. The Degree of Collaboration (DC) is also seen a linear growth from 0.89 to 0.98, with mean DC of 0.97 during 1999–2018. The value of Collaboration Coefficient increased from 0.551 in 1999 to 0.636 in 2018 indicating the share of multi-authored papers constantly increasing. The study also found that no significant difference was observed between CC values and MCC values due to the dominating multi-authored papers throughout the study period. The Collaborative Index for the whole period of study was found to be 3.34, which is almost equivalent to the global standard of 3 authors per paper (Adams et al., 2019).

This study indicates that the pace of international collaboration is higher than the domestic and local (within NITs) collaborated journal articles. In comparison to the overall growth, one could see a growth in the International collaborated and local (within NITs) collaborated journals articles. Whereas, the domestic collaborations have seen a declining trend. It is also observed that the international collaborations are associated with the greater citation impact with the highest ACPP, followed by domestic collaborations. The study reveals that the local (within NITs) collaborated journal article publications have not received good number of citations. It is also noted that the mean of DCI was 108.9 and mean of ICI was 89.45 for the overall period of study, which indicate the proportion of journal articles published by NITs in domestic collaboration is more than the world

average and proportion of international collaboration is lower than the world average. Hence, it is very important for the NITs to increase the proportion of international collaborations thereby increasing the impact of research publications by NITs as international collaborations attract more citations than the domestic or local collaborations.

## REFERENCES

1. Adams, J., Pendlebury, D., Potter, R., & Szomszor, M. (2019). *Global research report: Multi-authorship and research analytics*. London: Clarivate Analytics.
2. Ajiferuke, I., Burell, Q., & Tague, J. (1988). Collaborative coefficient: A single measure of the degree of collaboration in research. *Scientometrics*, 14(5-6), 421-433.
3. Bala, A., & Kumari, S. (2013). Research performance of National Institutes of Technology (NITs) of India during 2001-2010: A bibliometric analysis. *SRELS Journal of Information Management*, 50(5), 555-572.
4. Banshal, S. K., Singh, V. K., Basu, A., & Muhuri, P. K. (2017). Research performance of Indian Institutes of Technology. *Current Science*, 112(5), 923-932.
5. Banshal, S. K., Solanki, T., & Singh, V. K. (2018). Research performance of the National Institutes of Technology in India. *Current Science*, 115(11), 2025.
6. Choi, D. G., Lee, H., & Sung, T. K. (2011). Research profiling for 'standardisation and innovation'. *Scientometrics*, 88(1), 259-278.
7. Council of NITs. (n.d.). About National Institutes of Technology. Retrieved October 08, 2020, from <http://nitcouncil.org.in/index.php/site/console/siteAboutNit>
8. Garg, K. C., & Padhi, P. (2001). A study of collaboration in laser science and technology. *Scientometrics*, 51(2), 415-427.
9. Gracio, M.C., Oliveira, E.F., Gurgel, J.A., Escaloan, M.I. Gurrerero, A.P. (2013). Dentistry Scientometrics analysis: A comparative study between Brazil and other most productive countries in the area. *Scientometrics*, 95(2), 753-769.
10. Hasan, N., & Singh, M. (2015). Research output of Indian Institutes of Technology (IITs): A scientometric study. *Journal of Knowledge & Communication Management*, 5(2), 147-160.
11. Katz, J. S., & Martin, B. R. (1997). What is research collaboration?. *Research Policy*, 26(1), 1-18.
12. Lawani, S. M. (1980). Quality, collaboration, and citations in cancer research: a bibliometric study (PhD thesis). *Florida: Florida State University*.
13. Pradhan, B., & Sahu, S. C. (2018). Bibliometric Analysis of Research Publications of Indian Institute of Technology (IIT's) Based on Published Literature as Reflected in Scopus. *SRELS Journal of Information Management*, 55(5), 292-298.
14. Savanur, K. P., & Srikanth, R. (2010). Modified collaborative coefficient: A new

- measure for quantifying the degree of researchcollaboration. *Scientometrics*, 84(2), 365-371.
15. Shettar, I. M., & Hadagali, G. S. (2020). Scientometric Analysis of Research Publications of National Institutes of Technology. *SRELS Journal of Information Management*, 57(2), 84-100.
16. Siddaiah, D. K., Gupta, B. M., Dhawan, S. M., & Gupta, R. (2016). Contribution and Citation Impact of Eight New IITs: A Scientometric Assessment of their Publications during 2010-14. *Journal of Scientometric Research.*, 5(2), 106-122.
17. Singh, Y., & Gupta, B. M. (2010). Mapping of Indian Engineering Research using Quantitative Indicators, 1999–2008. *COLLNET Journal of Scientometrics and Information Management*, 4(2), 1-12.
18. Subramanyam, K. (1983). Bibliometric studies of research collaboration: A review. *Journal of Information Science*, 6(1), 33-38.
19. Tamilselvan, N., Sivakumar, N., & Sevukan, R. (2013). Lotka's Law: A study with reference to the literature by faculties of National Institutes of Technology, India. *International Journal of Library and Information Science (IJLIS)*, 2(1), 19-34.
20. Vijayakumar, K. (2017). A Biblometric Analysis of Collaborative Research Trends in Indian Institutes of Technology 1994. *Journal of Advances in Library and Information Science*, 6(4), 334-338.

