

Is India Emerging as a Hub for Digital Twin Research? A Scientometric Inquiry

Kishore Dey^{1,*}, Dipanjali Chakraborty²

¹Librarian, Karunamoyee Library, Kolkata, West Bengal, INDIA.

²Engineer, Shell India, Chennai, Tamil Nadu, INDIA.

ABSTRACT

Introduction: Digital Twin represents a revolutionary technological paradigm that has attracted considerable interest from various fields of research. **Objectives:** This work performs scientometric analysis in order to explore the dynamics and development of digital twin research paying special attention to Indian contributions. **Methodology:** Information was collected from OpenAlex database on May 26, 2025, based on the keywords "digital twin" in the title and abstract fields with regard to works published only in English by Indian researchers within the period of 2015-2024. In total, 1,237 records were subjected to scientometric analysis in Microsoft Excel. **Results:** It should be noted that the research output exhibits steady growth with dominance of scientific articles in scientific communication. Indian contributions to international research in the field of digital twin have increased throughout the years under investigation. As can be seen from the authorship analysis, there is a clear tendency towards collaboration, which is evident from a high level of collaboration among researchers. In terms of author productivity, the results of analysis demonstrate skewness, similar to Lotka's law, according to which the largest number of authors publish one paper each. **Key Findings:** Steady increase in digital twin research output from Indian researchers (2015-2024). Publication Type: Scientific articles dominate the research communication landscape - Collaboration Trend: High level of collaborative research among authors - Author Productivity Distribution: Follows Lotka's law pattern with most authors contributing single publications - Sample Size: 1,237 English-language records analyzed - Data Source: OpenAlex database -Geographic Focus: Indian research contributions to the global digital twin field.

Keywords: Author Productivity, Digital Twin, India, Lotka's Law, OpenAlex, Scientometric.

Correspondence:

Mr. Kishore Dey

Librarian, Karunamoyee Library, Kolkata,
West Bengal, INDIA.

Email: kishore.ju29@gmail.com

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INTRODUCTION

The notion of Digital Twin has been developed over recent years, providing opportunities for creating virtual copies of actual systems that can be analyzed and optimized. Emerging initially from the fields of engineering and manufacturing, this innovative technology quickly gained momentum in areas including healthcare, smart cities, industrial automation, and others (Digital twin enabling technologies, Barricelli *et al.*, 2019; Fuller *et al.*, 2020). The development has been supported by progress in IoT, artificial intelligence, and big data analytics, which enable efficient collection, transfer, and processing of information. Digital twin research has gained considerable popularity over the last ten years due to its practical relevance. In particular, scholars have focused on the origins and potential future perspectives

associated with this innovation as well as possible applications in cyber-physical systems and digital transformation (Digital twin origin to future, Singh *et al.*, 2021; Digital twin benefits, Attaran and Celik 2023). At the same time, researchers have recognized the importance of systematic investigation of digital twin-related knowledge considering its complex nature (Digital Twin systematic review, Jones *et al.*, 2020).

Here, scientometrics emerges as an excellent instrument for conducting a quantitative evaluation of research tendencies, collaboration practices, and information dissemination in a specific scientific discipline. Scientific fields' intellectual architecture and development course can be elucidated using the scientometrics technique (Ivancheva 2008 Scientometrics methodology overview; Leydesdorff and Milojevic Scientometrics, n.d.). With the fast-growing number of scientific studies on digital twins, there is a demand to investigate their emergence and evolution, especially in less developed scientific areas like India. This study seeks to conduct scientometric analysis of digital twins research growth and dynamics, concentrating on the aspects of publication tendencies, authorship patterns, collaboration behavior, and sources' allocation, especially that of India.



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RELATED WORKS

The topic of Digital Twin has received a lot of interest from scholars owing to its immense transformational possibilities in different fields. Initial research has been concerned with the definition and conceptualization of digital twins, discussing their attributes, design considerations, and broad applicability. For example, Barricelli *et al.*, 2019 Digital Twin review conducted a thorough review of the definitions, attributes, and applications of digital twins, creating the foundation for an understanding of this concept. Also, Jones *et al.*, 2020 Digital Twin systematic review conducted a systematic review of the literature to define digital twin systems and their relevance in the context of cyber-physical systems. Other topics related to technological advancements and evolution of digital twin research have also been broadly addressed by scholars. Research like Fuller *et al.*, 2020 Digital Twin enabling technologies focused on exploring enabling technologies, limitations, and future research avenues related to digital twins, whereas Singh *et al.*, 2021 Digital twin origin to future looked at its past origin and future course.

Apart from the theoretical progress in this field, several research studies have paid attention to practical aspects related to the usage of digital twin technology. For instance, Attaran and Celik, 2023 Digital Twin benefits covered the topic of advantages, application areas, and difficulties of the digital twin implementation, whereas industry-based approaches identified important application areas and their benefits (IoT Analytics Digital Twin applications insights). In turn, specific application of digital twin technology to particular domains has also been researched, which illustrates the growth of research perspectives for this concept. For example, Zhao *et al.*, 2024 Digital Twin measurement technology investigated the application of digital twins to measurement technologies, whereas Lam *et al.*, 2024 Winter Simulation Conference digital twin focused on simulation technologies. Finally, the issue of organization and development of digital twins' researches has been considered from the engineering and manufacturing point of view.

Along with technological progress, there is an increased awareness of the importance of using scientometric and bibliometric methods to analyze research trends. Scientometrics is a discipline that helps evaluate the scholarly communication process, research productivity, and collaboration practices (Ivancheva, 2008). In their foundational research, scientists stressed that quantitative metrics are used to construct the intellectual structure of research areas (Leydesdorff and Milojevic, n.d.). Also, review-based articles show the importance of research output synthesis to detect trends and research gaps (Blumel and Schniederermann, 2020). It becomes essential for researchers to conduct systematic and quantitative analysis in rapidly changing scientific disciplines, including digital twin. Although there is a considerable amount of literature dedicated to digital twin, there is still a lack of systematic scientometric research, which specifically focuses

on the role of particular regions in the scientific development. Most existing works are related to studying global tendencies and technology aspects of digital twin applications. However, few studies explore the characteristics of publication process, collaboration dynamics, and research productivity in emerging communities, especially in India. Therefore, this paper aims to fill this research gap by conducting a scientometric analysis of digital twin publications with emphasis on India.

OBJECTIVES OF THE STUDY

- To assess the number of papers published about digital twins in India annually for 2015 to 2024;
- To investigate the distribution pattern of scientific publication between national and international platforms;
- To compare the rate of growth in India's scientific output in terms of digital twins;
- To determine the annual authorship trend for papers published;
- To analyze the collaboration rate among the authors of digital twin research;
- To measure the productivity of authors engaged in digital twin research;
- To rank the journals publishing digital twin research.

METHODOLOGY

In the current study, a scientometric method has been applied to evaluate the research trends in the field of digital twin in India. For this purpose, the data was collected from the OpenAlex database, a reliable and comprehensive resource for scientific information. Data were extracted from the OpenAlex database on 26 May 2025. Scientometric analysis involved employing the structured search process for the query: title and abstract containing "digital twin" AND country=India AND publication years=2015-2024 AND language=English. Consequently, there were 1,237 entries that comprised the dataset for the study.

The collected data included several bibliographic measures such as publication years, authors' names, affiliations (countries), and source titles (journals). The measures were selected for analyzing publication trends, authorship trends, collaboration among the authors, and distribution of publications across sources. Upon collecting the necessary data, they were exported to Microsoft Excel, where data processing was performed. Microsoft Excel became the main software platform used for data processing, cleaning, and analysis. Scientometric measures such as annual publication output, relative growth rates, degree of collaboration, authorship trends, and author productivity were calculated according to standard methods.

FINDINGS AND DISCUSSION

Digital Twin Research Output over the Years

The sources of Digital Twin research include articles published in journals, book chapters, reviews, pre-prints, datasets etc. the study had observed a total of 18219 publications in digital twin over the 6 years (see Table 1). Out of them, articles have shown a prominent and predominant contribution. The year wise distribution also shows how research output have gradually increased over the years. The digital twin research output consisting of book chapters comes second, closely followed by preprints. Reviews and datasets hold the fourth and fifth position respectively. The other formats fail to make significant impact in the overall research output.

Digital Twin research output on International and National Output

The following Table 2 demonstrates international and national (Indian) Digital Twin research output. In 2015, out of 58 published materials, 53 were result of international publication whereas only 3 of them were published in India. The output can be seen

showing gradual increase over the years and finally in 2024, out of 5104 published documents, India contributed to almost 11% of globally published Digital Twin research.

Relative Growth of Indian Research Output

The following Table 3 indicates the relative growth of national (India) output of Digital Twin publication as well as the doubling time for the literature. It includes all sources of publications. It can be clearly observed that the Relative Growth Rate (RGR) decreased from 2015 (0.8) to 2024 (0.5). Whereas the doubling time shows a gradual increase from 2015 (0.8) to 2024 (1.3). It can be deduced from the above table that relative growth has shown a progressive decline which means the increase rate is low in terms of proportion and this has been highlighted by doubling time for publication.

Authorship Pattern

Year-wise Authorship Pattern

Table 4 clearly shows that papers with 5 authors are maximum whereas papers with more than 5 authors are minimum over

Table 1: Year-wise Distribution of Research Output.

Document Type	Year										Total	%
	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024		
Articles	50	51	102	223	523	1029	1866	2778	4081	4163	14866	81.6%
Book	-	-	-	-	7	1	4	4	12	8	36	0.2%
Book chapters	-	4	3	14	77	109	138	273	500	372	1490	8.2%
Dataset	1	-	-	-	-	2	12	48	33	6	102	0.6%
Editorial	1	-	-	-	2	2	9	14	30	23	81	5.5%
Other	1	1	-	-	1	1	14	20	22	39	99	0.5%
Preprint	1	-	-	8	19	56	99	140	357	319	999	5.5%
Report	1	-	-	1	1	5	20	23	25	14	90	0.5%
Review	1	2	3	1	6	20	40	84	139	160	456	2.5%
Total	56	58	108	247	636	1225	2202	3384	5199	5104	18219	

Table 2: Distribution of International and National Output.

Year	International Output	National Output	Percentage
2024	4599	505	10.9%
2023	4844	355	7.3%
2022	3201	183	5.7%
2021	2117	85	4%
2020	1178	47	4%
2019	602	34	5.6
2018	233	14	6.0%
2017	98	7	7.1%
2016	54	4	7.4%
2015	53	3	5.7%
Total	16979	1237	

Table 3: Relative Growth Rate (RGR) and Doubling Time (Dt) of National Output.

Year	Publication output	Cumulative output	W1	W2	RGR	Dt
2015	3	3	1.098612	1.098612	0.847298	0.817894
2016	4	7	1.94591	1.94591	0.693147	0.999788
2017	7	14	2.639057	2.639057	0.693147	0.999788
2018	14	28	3.332205	3.332205	0.79493	0.871775
2019	34	62	4.127134	4.127134	0.564213	1.228258
2020	47	109	4.691348	4.691348	0.57651	1.20206
2021	85	194	5.267858	5.267858	0.664387	1.043067
2022	183	377	5.932245	5.932245	0.663535	1.044406
2023	355	732	6.595781	6.595781	0.524664	1.320846
2024	505	1237	7.120444	7.120444	0.524664	1.320846

Table 4: Year-wise Authorship Pattern of 'Digital Twin' Literature.

Year	1 Author	2 Authors	3 Authors	4 Authors	5 Authors	>5 Authors	Total
2015	-	1	2	-	-	-	3
2016	-	1	2	-	1	-	4
2017	-	2	2	1	2	-	7
2018	3	4	1	3	3	1	15
2019	3	13	6	8	4	-	34
2020	8	14	6	10	9	1	48
2021	7	17	15	12	32	2	85
2022	16	29	49	31	50	12	187
2023	15	60	72	72	127	8	354
2024	24	89	104	98	179	9	503
Total	76	230	259	235	407	33	1237

Table 5: Degree of Collaboration (C) as observed from 2015-2024.

Year	Single author		Multiple author		Total (Nm+N _s)	Degree of Collaboration C= Nm/(Nm+N _s)
	No. of publication (N _s)	%	No. of publication (N _m)	%		
2015	0	0	3	0.26	3	1
2016	0	0	4	0.34	4	1
2017	0	0	7	0.60	7	1
2018	3	3.95	12	1.03	15	0.8
2019	3	3.95	31	2.67	34	0.9
2020	8	10.53	40	3.46	48	0.8
2021	7	9.21	78	6.72	85	0.9
2022	16	21.05	171	14.73	187	0.9
2023	15	19.74	339	29.2	354	0.9
2024	24	31.58	479	41.26	503	0.9
Total	76		1161			0.91

Table 6: Distribution of Author based on Productivity.

No. of contribution(s)	No. of author(s)	Percentage (%)	Cumulative percentage (%)
1	3166	85.3	85.3
2	355	9.6	94.9
3	97	2.6	97.5
4	33	0.9	98.4
5	18	0.5	98.9
6	12	0.3	99.2
7	4	0.1	99.3
8	2	0.05	99.35
9	2	0.05	99.4
10	3	0.08	99.48
>10	19	0.5	99.98
Total	3711	100	

Table 7: Distribution of Author Productivity based on Lotka’s Law.

No. of papers (X)	No. of authors (Y) observed values	When n=3.16, expected values
1	3166	3166
2	355	354.2
3	97	98.4
4	33	39.6
5	18	19.6
6	12	11
7	4	6.8
8	2	4.4
9	2	3.1
10	3	2.2

the years. It also establishes the fact that when the no. of authors increases, their contribution to the paper significantly decreases.

Degree of Collaboration

From the Table 5, it can be deduced that the aggregate degree of collaboration for ‘Digital Twin’ literature over 2015-2024 is 0.91 which means, out of 1237 literatures, 91% of them are product of author collaboration. This clearly brings out the high level of collaborative research for ‘Digital Twin’.

Author Productivity

The study of author productivity is an important aspect in analysing the performance of research output. Generally, research activity is carried out by one person or a group of persons depending on the nature and aim of research. It also depends on the ability and efficiency of scientists. Depending on the skill and talent, a scientist may contribute to a quite number of papers, but it may not be the case for other scientists.

The analysis of author productivity (see Table 6) examines the trend of carrying out research in any discipline. This following section will solely focus on author productivity on ‘Digital Twin’. It can be observed that, 85.3% authors have made single contributions, whereas, two and three papers contributed by authors record second (9.6%) and third (2.7%) respectively. It is an interesting factor to notice that when the number of contributions increases, the number of authors decreases. It proves that, a greater level of research performance is noted only among few authors.

Lotka’s Law of Scientific Productivity

Lotka’s formula for scientific productivity is as follows:

$$y = \frac{C}{x^n}$$

Where,

X=Number of Publications,

Y=Relative Frequency of Authors with X publications,

C=Constants depending on the specified field.

Putting the value in above equation,

X=1, Y=3166,

We get, 3166=C/1n,

Therefore, C=3166,

Again, putting the value of X=2, Y=355,

We get,

$$355=3166/2n$$

$$2n=3166/355, =8.92$$

Table 8: Distribution of Journals as per Ranking.

Serial No.	Title of the journal	No. of Articles	%	Rank
1	IEEE Transactions on Industrial Informatics	211	8.0%	1
2	The International Journal of Advanced Manufacturing Technology	190	7.2%	2
3	Springer eBooks	183	7%	3
4	CIRP journal of manufacturing science and technology	181	6.9%	4
5	IEEE Access	171	6.4%	5
6	Procedia Manufacturing	169	6.4%	6
7	IFAC-PapersOnLine	159	6%	7
8	Journal of Manufacturing Systems	136	5.2%	8
9	International Journal of Production Research	124	4.7%	9
10	CIRP Annals	121	4.6%	10
11	IEEE Multimedia	118	4.5%	11
12	Procedia CIRP	110	4.2%	12
13	Systems	108	4.1%	13
14	Automation in Construction	104	4%	14
15	Computers in Industry	103	3.9%	15
16	Nature	100	3.8%	16
17	Robotics and Computer-Integrated Manufacturing	98	3.7%	17
18	IEEE Internet of Things Journal	87	3.3%	18
19	Engineering	82	3.1%	19
20	Manufacturing Letters	81	3.1%	20
	Total	2636		

Taking log on both sides,

$$n \log 2 = \log 8.92$$

therefore, $n=3.16$.

Lotka's law of scientific productivity is used to calculate the authors' productivity in bibliometric study (see Table 7) and this law stated that- "The number of authors making n contributions is about $1/n^2$ of those making one and proportion of all contributors that make a single contribution is about 60 percent. This means that out of all the authors in a field, 60% will have one publication, and 15% will be two publications, 7% of authors will have three publications and so on". The above table and figure explored the Lotka's law of scientific productivity with the chosen dataset. It was observed that, most of the observed and expected values were same. This in fact, justifies the skewed distribution of research output that only a few highly prolific authors contribute in most of the publications and majority of authors are occasional contributors. This therefore confirms a universal bibliometric pattern that can be observed in scientific publishing, showing inequality in productivity.

Ranking of Journals

Journals is one of the primary sources of information. A higher rate of periodicals can be a measure of growth in the field of knowledge. It is an established fact that in the field of science, there is apparently an increased rate of birth of journals to meet the rapid explosion of information. The following table shows the ranking of journals according to their productivity. For 'Digital Twin', a total no. of 3289 journals published 18219 articles (see Table 8).

Scope of the Study

The current research is limited to a scientometric analysis of the existing literature on digital twin published in the OpenAlex database. The literature review is limited to those publications which have used the keyword "digital twin" in their titles and abstracts and are in the English language during the period 2015-2024. Regionally, the literature review focuses on the studies conducted by the researchers from India while at the same time making comparisons with global trends in order to see where India stands regarding digital twin research.

The literature reviewed includes a wide range of scholarly writings including journal papers, book chapters, reviews, preprints, and

data sets among others. However, it is important to note that the research is limited to only the literature found in the OpenAlex database.

CONCLUSION

In this scientometric research, it is shown how the number of digital twins and its scope have rapidly grown and evolved during the time span of 2015-2024. As one can see, the number of research outputs has significantly increased on a global level. Moreover, journal articles have become the most prevalent type of scholarly publication within this topic. The constant growth of scientific publications shows how significant and diverse the use of digital twins has become across different spheres. When analyzing the distribution of national and international research contributions, it becomes evident that even though the number of global research outputs has rapidly increased, India's contribution has been growing consistently and reached a significant level lately. Nevertheless, one can note that its growth rate tends to stabilize. Moreover, an analysis of authorship patterns and collaboration among authors shows that there is a trend of collaboration between scholars. In particular, the results show that many researchers tend to co-author their papers in digital twins' field. The analysis of multi-authorship demonstrates a high level of cooperation, which is expected in digital twins' sphere because it is an interdisciplinary topic. The authorship productivity analysis proves that the number of publications written by authors.

The above trend is reinforced by Lotka's Law, which highlights the skewed distribution of scientific output. Additionally, journal ranking shows that a few key journals play an important role in disseminating knowledge on digital twin technology. Generally speaking, the findings of this research provide a good picture of the research status in the domain of digital twin, which is gaining importance due to the collaborative nature of the work done. The results of this research can be very helpful for policy makers, academics, and professionals who want to understand new trends in the field.

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ABBREVIATIONS

IoT: Internet of Things; **AI:** Artificial Intelligence; **RGR:** Relative Growth Rate; **Dt:** Doubling Time.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTION

Kishore Dey (Librarian, Karunamoyee Library) was responsible for data collection, conceptualization of the study, interpretation of results, critical review, supervision and preparation of the manuscript. Dipanjali Chakraborty (Engineer, Shell India) contributed through data analysis and interpretation of results throughout the research process. Both authors have read and approved the final version of the manuscript.

SUMMARY

The concept of Digital Twin has proven to be revolutionary technology, receiving considerable attention from various research fields. In this study, a scientometric analysis of Digital Twin research is performed with particular emphasis on contributions from India in the period of 2015-2024 through OpenAlex database. A total of 1,237 publications in English language were analyzed using Microsoft Excel software. It was found that there is continuous increase in research output, while journal articles serve as dominant source for communication of results. Research contributions from India to world literature on Digital Twins are consistently increasing throughout the entire analyzed period. Patterns of authorship have demonstrated clear preference for collaborations amongst researchers. Moreover, authorship productivity demonstrates a skewness in accordance with Lotka's law.

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