Asian Journal of Information Science and Technology
ISSN: 2231-6108 (P) Vol.4 No.1, 2014, pp.16-25

DOI: https://doi.org/10.51983/ajist-2014.4.1.93

Scientometric Dimension of Digital Architecture Research Output Based on Web of Science Database: A Global Perspective

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(Received on 15 January 2014 and accepted on 20 March 2014)

Abstract – **This study analyses the global publications output in Digital Architecture research during 1999-2013 on several parameters. The Web of Science Databases has been used to retrieve the data for 15 years (1999-2013) by the searching the keyword "Digital Architecture". Scientometric analysis of 6335 papers related Digital Architecture research output was undertaken. Most of the researchers preferred to publish their research results in journal articles; as such (5031 articles) 79.41% of articles were published in journals. On an average of 300 papers are published every year. Two and more authored papers constitute majority of the contributions and degree of collaboration amounts to 0.89. This shows that team research is prevalent in the area of Digital Architecture. It is observed that author productivity is not in agreement with Lotka's law, but productivity distribution data partially fits the law when the value of Chi-square to 727.71 Bradford's distribution the relationship between the zone is 1: a: a2, while the relationship in each zone of the present study is 25:258:1214 which does not fit into Bradford's distribution. North European Countries (40%) produces largest amount and Asian countries occupy the third place of the research output of literature related to Digital Architecture and English is the most predominant language used for publishing the literature related to Digital Architecture during the study period.**

Keyword: **Digital Architecture, Scientometric, Lotka's law, Bradford's distribution, Global level**

I. Introduction

Digital Architecture is the only guide that shows us how to create accomplished computer drawings by displaying and explaining the work of many of today's most justly celebrated design professionals. It gives us the foundation to understand how these international masters so deftly exploited computers, by providing a clear overview of the hardware, software, and input and output devices involved in digital media. It then showcases the conceptual studies, desktop formats, 3D renderings, digital hybrids, and animation of more than 50 top designers and firms. Each project comes with a succinct explanation of the design concept, drawing techniques, hardware and software used, and output media involved. Featuring an easy-to-use, loose-leaf format, Digital Architecture will be our ongoing reference on hybrid digital representation and an endless source of ideas and inspiration. Digital architecture uses computer modeling, programming, simulation and imaging to create both virtual forms and physical structures. The terminology has also been used to refer to other aspects of architecture that feature digital technologies.

The present study aims at analyzing the Scientometric Analysis of Digital Architecture based on Web of Science Database: A Global Perspective'. The major focus of the study is to apply the scientometric analysis with a view to analyse the evaluation and performance of research out put in Digital Architecture. This study related to authors, their productivity; collaborative patterns and other aspects is important and useful to understand the mechanism underlying the growth of knowledge of a discipline. This study is also to analyse the performance and evaluation of Digital Architecture research output interms of its content and coverage growth rates, sourcewise. Degree of collaboration, Activity and priority index, Areas of research concentration, author productivity, authorship Pattern, and word frequency and citation analysis is also noted.

II. Objectives

The researcher has framed the following objectives for the purpose of present research.

1. To examines the growth of literature in Digital architecture in scientometric the period 1999 to 2013.
2. To examine the various sources of research publications in digital architecture research in Global level.
3. To examine the premier institutions, publishing the research output in digital architecture research at the Global level.
4. To identify the nature of Authorship pattern and determine the degree of collabration.
5. To identify the proportion of single and multi-authored papers of digital architecture research output.
6. To prepare a ranking list of core journals conforms the implication of Bradford's law.
7. To test the applicability of Lotka's law to the scientific productivity of authors.
8. To identify the Countrywise research output performance in Digital architechture in bibliometrics.
9. To identifiy the word frequency research output in Digital architechture at global level.

III. Sources and Methods

The Science Citation Index (web of science) database was used for collecting the citations to the publications. For the present study the data has been retrieved from Science Citation Index (Web of Science) database.The data for the study was downloaded from the web of science database in May 2013. Web of science is an international multidisciplinary database indexing over 7000 international peer reviewed journals in science and technology, besides more than 500 international conference/seminar proceeding,. The data is fed in to computer using MS-Excel software and the statistical package for social sciences(SPSS) for analysis. Publications data for 15 years from 1999 to May 2013 were used for analyzing the growth and impact of university research. A large time coverage data has been used to ensure accurate results. In addition, citations data for qualitative analysis of Global research output was used. The study explores the research concentration in digital architecture and journals of priority in publishing digital architecture articles. The journal information regarding the country and the subject of journals are obtained from 'Ulrich's International Periodical Directory'.

IV. Indicator Used

Following indicators have been used in the analysis of data.

A. Collaboration Co-efficient

In order to identify the degree of collaboration, the research or has adopted K. Subramanyam's formula.The formula is C = Nm/Nm+Ns

Where, C = Degree of collaboration in a discipline

Nm = Number of multiple authored papers

Ns = Number of the single authored papers

B. Priority Index

Priority index (PI) has been calculated the properly normalize the size of country and the size of the subject field. Priority India is computer using the following formula.

$$\text{Priority Index} = \frac{(N_{ij}/N_{jo}) \times 100}{(N_{oj}/N_{oo})}$$

Where

N_{ij} - the number of publications of country **i** in subfield **j**

N_{io} - the number of publications of country **i** is all subfields of the major fields.

N_{oj} - the number of publications of all countries wise the total world output in subfield **j**

N_{oo} - the number of Publications in all subfields of those major fields.

The value of PI = 100 indicates that research priority of a country for a given subfield corresponds precisely to the average of all countries. PI=100 indicate average priority PI >100 indicates higher than average priority and PI<100 indicates, lower than average priority.

C. Activity Index

To Activity index (AI) characterises the relative research efforts of a country in a given subject field. It is defined as

$$A I = \frac{\text{(Given field's share in the individual's publications output)}}{\text{(Given fields share in the world's publication's output)}}$$

AI =100 indicates that the country's research efforts in given field corresponding precisely to the worlds average. AI >100 reflects higher activity than the world's average, and AI <100 indicates low than average effort dedicated to the field under study.

In the present context, AI for Index has been calculated for different years to see how India performance changed during different years by using the above formula but in a modified way. Here AI is calculated as suggested by karki (2000).

$$A I = \frac{\{\text{(Individual output in a particular year) / Total world output)}\}}{\{\text{(World's output in particular year) / Total world's output)}\}}$$

IV. Analysis and Discussion

Table I shows year-wise research output from 1999 to 2013. 6335 scholarly papers published within fifteen years. Highest percentage of papers were published in the year 2012, 2011 and 2009 constituting 9.39 % and 8.71% and 8.70% respectively. In the year 2010, the publication percentage was 8.37%. 7.92% of publications published in 2008. The years 2006 and 2005 contributed 7.56% and 7.12%. Only 7.09% of papers ware published in 2007. The year 2001 had a very least percentage of only 4.55 in terms of publication of research papers.It could be deduced from the above discussion that, among the study period the research paper publication trend is increasing and decreasing. Highest percent of publication published in 2012. In the year 2001, the publication of research paper was minimal.

Table I Year-Wise Distribution Of The Research Output

Sl.No.	Publication of Year	Publication Output	Percentage	TLCS	TGCS
1	1999	320	5.05	332	4355
2	2000	306	4.83	281	4887
3	2001	288	4.55	228	4003
4	2002	319	5.03	178	6832
5	2003	371	5.86	352	5727
6	2004	370	5.84	368	5440
7	2005	451	7.12	380	5608
8	2006	479	7.56	313	4458
9	2007	449	7.09	368	4940
10	2008	502	7.92	283	4560
11	2009	551	8.70	221	3300
12	2010	530	8.37	135	2179
13	2011	552	8.71	80	1205
14	2012	595	9.39	23	366
15	2013	252	3.98	3	23
Total		6335	100		

Data presented in table II indicates the source-wise publication of research output in Digital Architecture in bibliometric Analysis between 1999 and 2013. It could be noted that out of the total 6335 publications, Journals Articles form of publication constitute 79.41%, Conference Proceedings 17.99%, Review 1.44%, Editorial 0.24%, Book Chapter 0.09%, Reprint 0.08%, letter 0.14 %, software 0.02% of the total publications, during the study period. It could be deduced from the above discussion that journal articles predominate over other sources of publications. It is due to the pivotal place of journals as a medium of scientific communication than any other formpublication; Majority of research output published in journal in general.

Table II Distribution of Source-Wise Publication of Research Output

Sl.No.	Document Type	Recs	%	TLCS	TGCS
1	Article	5031	79.41	2601	43449
2	Article; Proceedings Paper	1140	17.99	875	10577
3	Review	91	1.44	43	3621
4	Book Review	22	0.35	0	0
5	Editorial Material	15	0.24	6	104
6	Letter	9	0.14	5	47
7	Review; Book Chapter	6	0.09	0	40
8	Reprint	5	0.08	6	21
9	Article; Book Chapter	4	0.06	1	3
10	Correction	4	0.06	8	12
11	News Item	3	0.05	0	0
12	Meeting Abstract	2	0.03	0	1
13	Art Exhibit Review	1	0.02	0	0
14	Biographical-Item	1	0.02	0	1
15	Software Review	1	0.02	0	7
	Total	6335	100		

Table III Shows that activity and priority index of articles in journals, the proportion of contribution to the productivity and in terms of growth are seen from two different angles. The first one is volume of article produced by a specific variable (articles in journals) in different years and thus the extent of increase and the second one is the volume of growth in different years in relation to the Indian productivity. In the proportion of the contribution of analyses the productivity and in terms of growth it is seen from two different angles. The first one is volume of article produced by a specific (variable) in different years and thus the extent of increase and the second one is the volume of growth in different years in relation to the whole or overall productivity.

Table III Activity and Priority Index of Articles in Journals Research Output

S. No.	Year	R.O/P of JA	COP=A	W.O/P	WOP=B	A/B=AI Value	PI value
1	1999	253	5.02	320	5.05	0.99	99
2	2000	226	4.49	306	4.83	0.92	92
3	2001	205	4.07	288	4.54	0.89	89
4	2002	227	4.51	319	5.03	0.89	89
5	2003	251	4.98	371	5.85	0.85	85
6	2004	224	4.45	370	5.84	0.76	76
7	2005	300	5.96	451	7.11	0.83	83
8	2006	341	6.77	479	7.56	0.89	89
9	2007	363	7.21	449	7.08	1.01	101
10	2008	402	7.99	502	7.92	1.00	100
11	2009	471	9.36	551	8.69	1.07	107
12	2010	466	9.26	530	8.36	1.10	110
13	2011	502	9.97	552	8.71	1.14	114
14	2012	565	11.23	595	9.39	1.19	119
15	2013	235	4.67	252	3.97	1.17	117
	Total	5031		6335			

The results of activity Index values are given in the table III below. It can be found that the result of Activity index formula table of the overall study periods witnessed higher activity in the years 2007 to 2013. Remaining years have lower activity as noted in 1999 to 2006. It could be inferred from the above table, that one could clearly see what indicates the articles in journals is precisely corresponding to the World average value.

In order to determine the collaboration in quantitative terms, the formula suggested by K. Subramanyam was tested. It is inferred from the table IV that at the aggregate level, the degree of collaboration is of 0.89 during the study period 1999 to 2013 i.e, that is out of total 6335 literature published, 96% of them or published under the joint author of publications in Digital Architecture research output.The period wise analysis indicates that its level is somewhat less in the first period [1999-2005: 0.86] and it has shown. An increasing trend during the period [2006-13: 0.91]. This brings out clearly the high level of prevalence of collaborative research in Digital Architecture.Based on this study, the result of the degree of collaboration C=0.89 i.e., 89 percent of collaboration authors articles published during the study periods.

The Lotka's law of author productivity is tested with the applications of scientific productivity Chi-square model, and it is applied in relation to number of authors contributing to the number of publications. Potter (1981) identified the Lotka's fraction 1/na = 4.65 on the basic of Euler - maclaurin formula of summation. This model is applied in the present study.

Table IV Degree of Collaboration

Year	Single Author		Multiple Author		Total (%)	Degree of collaboration	Mean Degree of Collaboration
	No. of Out put	Percentage	No. of Out put	Percentage			
1999	57	17.81	263	82.18	320(5.05)	0.82	
2000	62	20.26	244	79.73	306(4.83)	0.79	
2001	46	15.97	242	84.02	288(4.54)	0.84	
2002	38	11.91	281	88.08	319(5.03)	0.88	
2003	32	8.62	339	91.37	371(5.85)	0.91	
2004	30	8.10	340	91.89	370(5.84)	0.91	
2005	52	11.52	399	88.47	451(7.11)	0.88	0.86
2006	42	8.76	437	91.23	479(7.56)	0.91	
2007	51	11.35	398	88.64	449(7.08)	0.88	
2008	51	10.15	451	89.84	502(7.92)	0.89	
2009	49	8.89	502	91.10	551(8.69)	0.91	
2010	47	8.86	483	91.13	530(8.36)	0.91	
2011	48	8.69	504	91.30	552(8.71)	0.91	
2012	49	8.23	546	91.76	595(9.39)	0.91	
2013	17	6.74	235	93.25	252(3.97)	0.93	0.91
Total	671	10.59	5664	89.40	6335	0.89	

The Chi-square can be computed as (f-p) 2/p, where f = observed number of authors with "n" publications; p = Expected number of authors. In this study, the productivity of Digital Architecture research scientists is examined. At the first observation, the analyzed data invalidate Lotka's findings that the proportion of all contributions that make a single contribution is less than 60 percent. Further, Lotka's Chi square model confirms the source trend. It explains the fact that the calculated x^2 value is 727.32 which is less than the tabulated value at 5% level of significance.

Table V Showing Lotka's Law of Author Productivity

No. of Publication	Observer No. of Authors with n (an) or F	Observed % of authors 100 X an/ al	Expected No. of Authors ($an=al/n^2$) (P)	Expected percentage of authors predicate by Lotka's $100/n^2$	$(F-P)^2/p$
1	3100	100	3100	100	0
2	211	6.80	775	25	410.44
3	136	4.38	344.44	11.11	126.14
4	117	3.77	193.75	6.25	30.40
5	63	2.03	124	4	30.00
6	59	1.90	86.11	2.77	8.53
7	58	1.87	63.26	2.04	0.43
8	49	1.58	48.43	1.56	0.00
11	39	1.25	25.61	0.82	6.98
12	34	1.09	21.52	0.69	7.22
14	33	1.06	15.81	0.51	18.66
15	26	0.83	13.77	0.44	10.84
16	25	0.80	12.10	0.39	13.72
19	24	0.77	8.58	0.27	27.66
21	23	0.74	7.02	0.22	36.28
			Total	X^2	727.37

The analysing the below given table VI, it is observed that totally 1497 journals published 6279 Articles. It could be cited in the present study the journals are ranked on the basis of their published papers on their maximum number of publication among the 1497 journals "IEEE Journal of Solid-State Circuits" has published. The highest number of Articles which is calculated to 390 Article (16.83%) results is the first rank in the field of Digital Architechture. Followed by the journal of "IEEE Transactions on Circuits and Systems I-Regular Papers "Which has published 222 (9.58%) number of Articles occupying Second rank in the research area. The jounal of IEEE Transactions on Very Large Scale Integration (VLSI) Systems" has published 127 numbers of articles in the Digital Architechture occupying the third rank. Next the journal name 'IEEE Transactions on Circuits and Systems II-Express Briefs "is the fourth rank and "IEEE Transactions on Circuits and Systems II-Express Briefs" is placed in the fifth rank. In Accordance to the research has given the ranks according to their higher publication in the field of Digital Architechture upto 35 ranks.

The Bradford's Law explains that a group of journals could be arranged in an order of decreasing productivity and reveals that journals, which yield the most productivity, are the last. According to this law, journals are to be grouped into a number of zones each producing a similar number of articles. However, the number of journals in each zone will be increasing rapidly. Then the relationship between the zone is 1: a: n2. Table VII shows the observation that a very small group of twenty five periodicals with 33.89% of articles. While the third larger group of 2128(33.99%) articles and the first vast largest zone of 2455 (39%) periodicals yield the second large group of 1214 articles are references (19.33%).

It could be deduced from the above discussion that the first twenty five journals covered more number of articles published. The next 258 journals covered 2455 articles. The remaining 1214 journals covered the 1696 articles. According to Bradford's distribution, the relationship between the zone is $1:a:a^2$ while the relationship in each zone of the present study is 25:258:1214 which does not fit into Bradford's distribution.

Table VI Distribution of Journal Article In Top Number of Published Contribution

Sl.No.	Author	Recs	%	TLCS	TGCS
1	IEEE Journal of Solid-State Circuits	390	16.83	937	8062
2	IEEE Transactions on Circuits And Systems I-Regular Papers	222	9.58	223	1639
3	IEEE Transactions on Very Large Scale Integration (VLSI) Systems	127	5.48	89	1112
4	IEEE Transactions on Consumer Electronics	124	5.35	55	621
5	IEEE Transactions on Circuits And Systems II-Express Briefs	117	5.04	150	811
6	Analog Integrated Circuits and Signal Processing	111	4.79	15	171
7	IEEE Transactions on Nuclear Science	108	4.66	97	901
8	IEICE Transactions on Electronics	82	3.53	20	221
9	IEEE Transactions on Microwave Theory And Techniques	76	3.28	93	1017
10	IEEE Transactions on Instrumentation And Measurement	74	3.19	21	349
11	IEEE Transactions on Circuits And Systems II-Analog and Digital Signal Processing	70	3.02	191	1315
12	Electronics Letters	66	2.84	28	132
13	IEICE Transactions on Fundamentals Of Electronics Communications And Computer Sciences	61	2.63	23	142
14	Journal of Instrumentation	61	2.63	0	362
15	Nuclear Instruments & Methods in Physics Research Section A-Accelerators Spectrometers Detectors and Associated Equipment	59	2.54	16	366
16	IEEE Communications Magazine	53	2.28	48	704
17	IEEE Transactions On Circuits And Systems For Video Technology	47	2.02	50	509
18	Journal Of VLSI Signal Processing Systems For Signal Image And Video Technology	45	1.94	47	362
19	Proceedings Of The IEEE	40	1.72	27	1486
20	IEEE Transactions On Signal Processing	39	1.68	39	263
21	Microelectronics Journal	39	1.68	6	90
22	IEEE Transactions On Power Electronics	37	1.59	83	843

Table VIII indicates the institution wise research productivity in the field of Digital Architecture research output. Totally 3838 institutions are brought out the research output of the field of whole sample data. Here the researcher has taken the first 30 higher publication priority of their highest research output institutions only. Given the ranks are by their highest productivity of research output on Digital Architecture.

It could be observed that Univ Calif Los Angeles, institutions have the high 90 (1.42%) productivity of this field during the study period. This analysis has proved by (There is a considerable level of inter – institution variation in the research output performance of Digital architecture research) hypothesis. “MIT” which given in number of publications 82 (1.29%) and stood in second rank with 106 TLCS 1551 TGCS, “Texas Instruments Inc“ has brought out of the publications 76(1.19%) third rank with 216 TLCS 1501 TGCS. “Natl Chiao Tung University” has stood the rank fourth in order (0.96%) in reflecting output performance of Digital architecture research along with 35 TLCS 457 TGCS. Remaining institutions (Natl Taiwan Univ, Univ Toronto, Stanford Univ, Georgia Inst Technol, Nanyang Technol Univ, etc) were having below 100 publications.

It could be observed that Univ Calif Los Angeles, institutions have the high 90 (1.42%) productivity of this field during the study period and highest TLCS and TGCS are scaled. This analysis has proved by twelfth (There is a considerable level of inter – institution variation in the research output performance of Digital architecture research) hypothesis.

Table VII Showing Ranking Journals According to Bradford Distribution

Sl.No.	No. of Journals	No. of Articles	Total No. of Articles	Cumulative No. of Articles
1	1	390	390	390
2	1	222	222	612
3	1	127	127	739
4	1	124	124	863
5	1	117	117	980
6	1	111	111	1091
7	1	108	108	1199
8	1	82	82	1281
9	1	76	76	1357
10	1	74	74	1431
11	1	70	70	1501
12	1	66	66	1567
13	1	61	61	1628
14	1	59	59	1687
15	1	53	53	1740
16	1	47	47	1787
17	1	45	45	1832
18	1	40	40	1872
19	2	39	78	1950
20	1	37	37	1987
21	2	36	72	2059
22	1	35	35	2094
23	1	34	34	2128
24	1	33	33	2161
25	2	32	64	2225
26	1	31	31	2256
27	2	30	60	2316
28	1	29	29	2345
29	1	28	28	2373
30	1	27	27	2400
31	2	26	52	2452
32	2	25	50	2502
33	4	24	96	2598
34	2	23	46	2644
35	1	22	22	2666
36	4	21	84	2750
37	2	20	40	2790
38	3	19	57	2847
39	3	18	54	2901
40	6	17	102	3003
41	4	16	64	3067
42	4	15	60	3127
43	3	14	42	3169
44	10	13	130	3299
45	7	12	84	3383
46	11	11	121	3504
47	12	10	120	3624
48	10	9	90	3714
49	21	8	168	3882
50	20	7	140	4022
51	27	6	162	4184
52	35	5	175	4359
53	56	4	224	4583
54	126	3	378	4961
55	230	2	460	5421
56	858	1	858	6279
Total	1497	2614		

V. Findings and Conclusion

The findings of the present lead to the following concluding remarks.

The finding of growth of publication of Digital Architecture research output brings out the research paper published trend in increasing trend. The overall study period the highest percentage publication published in 2012.

The findings of Activity and Priority Index value of journal Articles in the study period, seven of years have higher activity Index value, and the remaining eight years has under activity Index. Higher activity value means "the value is more than 1.0" under activity Index value means "the value is less than 1.0".

The find output author contribution"Kim J" published highest number of articles for the study period with 39 records, consecutive authors "Kim S" are published next highest number of articles for the study period with 20 records. "Muhamed K" having highest Global Citation Scores of 597 with just 12 publications followed by "Balsara PT" is having Global Citation Score of 256 with just 10 publications, while Kim S having lowest Global Citation Score of 48 with just 20 publications.

The findings of author productivity in terms of Lotka's law implications reveal the following facts that the analyzed data invalidate Lotkas findings. Lotka's Chi square model confirms the source trend. It explains the fact that the calculated x^2 value is 727.32 which is less than the tabulated value at 5 percent level of significance.

Table VIII Showing Distribution of Research Output By Institutions Wise

Sl.No.	Institution	Recs	%	TLCS	TGCS
1	Unknown	124	1.95	26	300
2	Univ Calif Los Angeles	90	1.42	106	1551
3	MIT	82	1.29	125	1719
4	Texas Instruments Inc	76	1.19	216	1501
5	Natl Chiao Tung Univ	61	0.96	35	457
6	Natl Taiwan Univ	59	0.93	65	825
7	Univ Calif Berkeley	59	0.93	70	1209
8	Stanford Univ	53	0.83	73	1132
9	Georgia Inst Technol	51	0.80	40	3917
10	Nanyang Technol Univ	51	0.80	37	319
11	Univ Toronto	49	0.77	95	964
12	Politecn Milan	46	0.72	36	400
13	Korea Adv Inst Sci & Technol	43	0.67	33	395
14	Ist Nazl Fis Nucl	42	0.66	4	406
15	Univ Michigan	42	0.66	17	529
16	Oregon State Univ	41	0.64	84	428
17	UCL	41	0.64	9	528
18	Texas A&M Univ	40	0.63	50	735
19	Chinese Acad Sci	39	0.61	16	139
20	Univ Calif San Diego	39	0.61	42	818
21	Univ Illinois	39	0.61	25	599
22	Univ Pisa	38	0.59	30	439
23	CNRS	37	0.58	17	574
24	Katholieke Univ Leuven	37	0.58	21	311
25	Univ Bologna	37	0.58	10	391

The findings of degree of collaboration analysis reveal the following facts that the case of single author contributed papers is less. It brings out clearly the high level prevalence of collaborative research in digital architecture.

The findings a journal source wise research output performance in Digital Architecture point out the following facts. It is observed that among the 1497 journals only seven journals have hundred and more than hundred articles in Digital Architecture, those top are first journals is “IEEE Journal of Solid-State Circuits” second is “IEEE Transactions on Circuits And Systems I-Regular Papers” Third is “IEEE Transactions on Very Large Scale Integration (VLSI) Systems” and fourth is “IEEE Transactions on Consumer Electronics” respectively.

The findings of classification of journals according to Bradford distribution reveal the facts the first twenty five journals covered more number of articles published. The next 258 journals covered 2455 articles. The remaining 1214 journals covered the 1696 articles. According to Bradford’s distribution, the relationship between the zone is $1:a:a^2$ while the relationship in each zone of the present study is 25:258:1214 which does not fit into Bradford’s distribution.

The findings of country wise analysis examine the following facts. The European Country top the list in using number cowards in the literature in Digital Architecture in bibliometric the North American countries the second, the Asia countries the third, the Oceania countries and the African countries the last respectively.

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