# Tacit Knowledge Management in Engineering Industries: A Bibliometric Analysis


**Pawankumar Saini and Pradnya Chitrao**

**Abstract** Using a bibliometric methodology, this paper examines scientific research in the topic of tacit knowledge management in engineering companies. To that purpose, this report examines 705 publications from the Scopus database using several performance indicators, including total articles, total citations, and citations per paper. This paper also evaluates the most productive and well-cited authors, important subject areas, publication sources, countries, and institutions. The collection included publications published in scholarly journals between 1983 and 2021. The evolution of the research of tacit knowledge management is summarized in this publication. Our findings show that the most cited papers are from the United States and Norway, respectively. The most productive year in terms of published articles is 2010, whereas the most successful year in terms of citations is 2002. The findings could aid future research on this subject.

**Keywords** Tacit knowledge management · Knowledge management · Bibliometric analysis · Systematic review · Analysis of citations · Engineering industries

## 1 Introduction

Nonaka and Takeuchi talked about the volatile markets and the shifting competition, which is truer today than it ever was [1]. Updated production knowledge is crucial for firms to prevent diminishing returns on their stock of knowledge capital as technology evolves at a rapid pace [2]. When businesses recognize the value of information and

P. Saini (✉)
Symbiosis International University,Pune, India
e-mail: pawankumarsaini09@gmail.com

P. Chitrao
Symbiosis Institute of Management Studies,A Constituent of Symbiosis International University,Pune, India
e-mail: pradnyac@sims.edu



A. Joshi et al. (eds.), *Information and Communication Technology for Competitive Strategies (ICTCS 2021)*, Lecture Notes in Networks and Systems 400,
https://doi.org/10.1007/978-981-19-0095-2_65

begin to accumulate and preserve it, small- and medium-sized businesses can use it to investigate problems and develop solutions, resulting in a structure that facilitates efficiency and effectiveness [3]. A key part of knowledge management is knowledge sharing, which has become the leading factor for success in an organization [4]. A firm as a knowledge-creating organization is a crucial component of the knowledge-based view of the firm, which contends that knowledge and the ability to produce and use it are the most essential sources of a firm's long-term competitiveness [5]. Knowledge is a fluid combination of experience, values, contextual information, and expert insight that aids in the evaluation and assimilation of new information and events. This type of knowledge arises and is utilized exclusively in the minds of those who know [6]. Tacit knowledge (TK) has been identified as a crucial resource for long-term competitive advantage and company expansion [7]. Few companies make a concerted attempt to uncover TK, obscuring implicit knowledge [8]. Michael Polanyi talks about one of the key aspects of TK, that "we know more than we can tell" [9]. As per Haldin-Herrgard T, one of the main problems in TK sharing is the unconsciousness of TK in the minds of people and the difficulty of using it [10]. According to Howells, TK can be acquired in informal ways as it is non-codified and disembodied know-how [11]. As per Jones and Leonard, we need to find ways of converting TK to organization knowledge by considering the different moderating factors, so that many more acquire the knowledge and use it [12]. Paolino, Lizcano, Lopez, and Lloret say that TK is unlimited as it expands the more it is used [13]. As per Mohajan, a lot of TK creation and spread depends on individuals' social relationships and attributes [14].

We hope to gain a better understanding of the research that has been done so far and the areas in which it needs to be done further in the field of tacit knowledge management in the engineering sectors. We use bibliometric analysis to scan the arena of TK management in this research. Alan Pritchard used the term bibliometrics to describe the application of mathematical and statistical tools to books and other forms of communication [15, 16]. Academic journals, books, patents, proceedings, and other sources of information (i.e., citations, keywords, titles, journals, authors, institutions, and so on) provide an important sample for statistically performing science evaluation research through a methodical, transparent, and repeatable review process [15, 17–19]. It also aids in identifying the most prolific researchers and institutions, identifying alterations in discipline boundaries, and presenting the "big picture" of current research time [20, 21]. Not just for research, but also for policymaking and practice, the definition of intellectual structure and the research-front of scientific domains is critical [22]. It is becoming more popular as a technique for evaluating scholarly quality and output [23]. Journal-specific studies have also emerged, other than the topic-centric bibliometric analysis [24–29]. The paper's main contribution is a complete bibliometric analysis of "Tacit Knowledge Management in Engineering Industries" using the Scopus database, as well as the expansion of research in this field through time. Most significant writers, extremely productive authors, countries, most referenced disciplines, and highest contribution institutions have all been discussed.

## 2 Data Collection and Method

We collected the data from SCOPUS database, which is a widely referred repository [30]. The query for extracting the documents included the words "tacit", "knowledge", "engineer", and "industry", all with an Asterix so that all the related words like plural forms can be included. Further, we also included the words "firm" and "organization" as it is closely related to the word "industry". The query string thus generated on 3rd of July 2021 was: (TITLE ( tacit* ) AND TITLE ( knowledge* ) AND TITLE ( engineer* ) AND TITLE ( industr* ) OR TITLE ( firm* ) OR TITLE ( organization* ) ). We obtained various tags from the Scopus database. The numerous performance characteristics collected from the bibliometric study, such as total articles, co-authors per article, articles per author, authors per article, total citations, and citations per article, are shown in this work.

## 3 Results and Discussion

The main information that emerged from the extracted documents based on the query was that articles made up 39% of the documents, conference papers 51%, and the remaining 10% consisted of books, book chapters, conference review, editorials, and reviews. The entire time span covered by Scopus was considered, which is 1983–2021. The 705 documents are available from 465 sources. The average citations per document is 17, and there are 21572 references made in these documents. A total of 1602 authors contributed toward research in this area. There are 166 documents written by single authors, which means that there are 539 co-authored documents. Multiple-author articles have a bigger impact than single-author articles since they are more likely to receive citations [31]. The collaboration index is 2.71. We have 1745 author's keywords, and there are 3868 keywords plus. In this section, we have conducted the performance analysis, which includes descriptive bibliometrics and evaluative bibliometrics [32]. We can get the research field's trends, influential authors, and most cited references, based on this [33]. We have presented bibliometric results of different performance parameters like research growth, most productive and highly cited authors, co-citation, keyword analysis, most sought after discipline, leading journals, country-wise analysis, institution-wise analysis, trending fields, and particularly influential papers.

### *3.1 Research Growth*

Table 1 displays the total number of papers published (TP) and the total number of citations (TC) received by the articles throughout the course of the year. The number of papers published and the number of patents issued are essential indices

**Table 1** Annual number of papers published and citations received

| Year | TP | TC | Year | TP | TC |
|---|---|---|---|---|---|
| 1983–1999 | 21 | 1174 | 2011 | 36 | 189 |
| 2000 | 10 | 550 | 2012 | 46 | 403 |
| 2001 | 11 | 677 | 2013 | 34 | 263 |
| 2002 | 16 | 1909 | 2014 | 45 | 177 |
| 2003 | 18 | 793 | 2015 | 36 | 226 |
| 2004 | 24 | 947 | 2016 | 37 | 375 |
| 2005 | 29 | 1329 | 2017 | 28 | 135 |
| 2006 | 41 | 796 | 2018 | 30 | 100 |
| 2007 | 34 | 356 | 2019 | 46 | 79 |
| 2008 | 39 | 774 | 2020 | 27 | 52 |
| 2009 | 31 | 355 | 2021 | 14 | 7 |
| 2010 | 52 | 320 | | | |

of scientific and technological production [34]. The very first paper recorded in this body of knowledge in the Scopus database was in 1983 by Glymour C., Stalker D.. TK management has received larger attention in the years starting from the year 1998, and it kept growing till 2006 after which the growth has been stable. This indicates a consistent interest in TK in industry. This could be because the number of researchers around the world is increasing, and due to internet, it has become convenient to carry out research [35–37]. The year 2010 saw the highest number of documents produced, totaling 52. From 1983 to 1999, the average number of papers per year was 1.23, whereas from 2000 to 2020, the average was 32 documents per year. We discovered that annual paper production is at an all-time high in the last two decades. Eugene Garfield coined the term "citation classic" (also known as "classic article" or "literary classic") to describe widely cited publications in a scientific domain. We will look at some of the citation classics, sometimes known as the "golden bullion of science" [38]. This could aid us in discovering critical information about the evolution of a particular discipline, allowing us to comprehend the history, present, and future of its scientific significance [39].

The two most cited papers have been authored by Asheim BT with a citation count of more than 760 in each of the articles. Other papers with more than 200 citations have been authored by Zucker LG, Demarest M, Almeida P, Mascitelli R, Bjrnson FO, and Lissoni. We can see that on an average, there have been 17 citations per document with 1.232 citations per year per document. There are more than 100 citations in 3.5% of the documents, 4.7% documents have citations between 50–100, and 17.5% have between 10 and 50 citations. Most citations are for publications between 2000 and 2010, indicating the focus that this subject received during this period. Articles published in the recent five years do not appear to have reached their maximum number of citations, and access to the first studies is not usually available to everyone; thus, they do not have a high number of citations [35, 36].

**Table 2** Source title with the highest number of articles

| Source title | TP | TC | C/D |
|---|---|---|---|
| Lecture Notes in Computer Science | 21 | 89 | 4.2 |
| Proceedings of the European Conference on Knowledge Management ECKM | 21 | 22 | 1.0 |
| Advances In Intelligent Systems and Computing | 14 | 6 | 0.4 |
| IFIP Advances in Information and Communication Technology | 9 | 13 | 1.4 |
| International Journal of Technology Management | 9 | 151 | 16.8 |
| ACM International Conference Proceeding Series | 7 | 4 | 0.6 |
| Automation In Construction | 7 | 397 | 56.7 |
| Communications In Computer and Information Science | 7 | 6 | 0.9 |
| Journal Of Construction Engineering and Management | 7 | 204 | 29.1 |
| Proceedings Of the Annual Hawaii International Conference On System Sciences | 7 | 31 | 4 |

## *3.2 Journals, Authors, Institutions, and Countries That Are at the Top of Their Fields*

The top 10 journals in relation to the quantity of papers published and the quantity of citations obtained are listed in Tables 1 and 2, respectively. The "Lecture notes in computer science" and "Proceedings of the European Conference on Knowledge Management ECKM" are the two sources with the most articles. However, the most important source that has made significant contribution around TK management in engineering industries is "Research Policy", which has received the highest citations (TC = 1212). The other significant sources with high citation per document (C/D) are "Journal of Technology Transfer" (C/D = 326) and "Management Science" (C/D = 330). Although the sources "Lecture Notes in computer science" and "Proceedings of the European Conference on Knowledge Management ECKM" have large number of articles, they have a low citation per document (Table 3).

An important perspective can be obtained from the data on authors, universities, and countries of papers citing the topic under study [40, 41]. Table 4 shows the top 10 authors, institutions, and countries based on the total number of papers (TP) produced, while Table 5 shows the top 10 based on the total citations (TC). R in the table denotes the ranking.

**Table 3** Source title with the highest number of citations

| Source title | TP | TC | C/D |
|---|---|---|---|
| Research Policy | 5 | 1212 | 242 |
| Journal of Technology Transfer | 3 | 979 | 326 |
| Management Science | 2 | 659 | 330 |
| Long Range Planning | 3 | 657 | 219 |
| Organization Science | 2 | 429 | 215 |
| Automation in Construction | 2 | 397 | 199 |
| Information and Software Technology | 3 | 391 | 130 |
| International Journal of Project Management | 3 | 323 | 108 |
| Journal of Product Innovation Management | 2 | 266 | 133 |
| Strategic Management Journal | 2 | 242 | 121 |

**Table 4** Authors, institutions, and countries with the most documents in the top 10

| R | Authors | TP | TC | Institution | TP | TC | Country | TP | TC |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Lin Y C | 11 | 256 | National Taipei University Of Technology | 10 | 180 | USA | 200 | 3447 |
| 2 | Wang L | 6 | 76 | University Of California | 7 | 796 | China | 141 | 682 |
| 3 | Liu Z | 5 | 9 | Loughborough University | 7 | 157 | UK | 110 | 1068 |
| 4 | Crcel-Carrasco J | 4 | 8 | Massachusetts Institute Of Technology | 7 | 80 | Japan | 70 | 181 |
| 5 | Heredia A | 4 | 12 | National Taiwan University | 6 | 152 | Sweden | 44 | 1000 |
| 6 | Liu X | 4 | 6 | University Of Twente | 6 | 29 | Brazil | 41 | 66 |
| 7 | Daneva M | 3 | 13 | Chalmers University Of Technology | 6 | 21 | India | 40 | 123 |
| 8 | Dingsyr T | 3 | 305 | Zhejiang University | 6 | 5 | Finland | 35 | 98 |
| 9 | Hamza H S | 3 | 2 | Georgia State University | 5 | 256 | Germany | 33 | 132 |
| 10 | Ibrahim R | 3 | 8 | Ching Yun University | 5 | 76 | Canada | 31 | 337 |

We can observe from these two tables that the authors, institutions, and countries with the most article creation do not necessarily have the most citations. National Taipei University of Technology, for example, published the most articles on TK management in engineering businesses. Despite being the leading article publisher in terms of quantity, i.e., the number of articles published, this institute has not been mentioned as frequently as other institutes. University of Oslo and University of Lund, on the other hand, have been cited in 1548 publications, whereas they published only two articles each. This shows how the number of citations received by a highly cited article affects the ranks of authors, universities, and countries. Lotka devised a criterion to classify author productivity: small producers publish one article, medium producers publish two to nine articles, and large producers write more than nine articles [42]. In this case, there is only one large producer, whereas there are 48 medium producers. When we look at the authors who have contributed the most, we see Lin YC publishing 11 articles, Wang L with 6 articles, Liu Z with 5 articles, and Crcel-carrasco J, Heredia A, and Liu X with 4 articles each. There are 8 other authors who have published 3 articles each. While Lin YC has received over 250 citations and Wang L has received over 70, the remaining authors have received less than 15 citations. We see that despite low productivity by Asheim BT, only two articles: "Knowledge bases and regional innovation systems: Comparing Nordic clusters" and "Regional innovation systems: The integration of local 'sticky' and global 'ubiquitous' knowledge", his total citation count is above 1500, which is the highest [43, 44]. The other two articles with the third and fourth highest citations are by Zucker, Darby, and Armstrong: "Commercializing knowledge: University science, knowledge capture, and firm performance in biotechnology" and by Demarest: "Understanding knowledge management" [45, 46].

### *3.3 Relationship Between Leading References by Leading Authors and the Top Key Words*

Figure 1 shows an interesting three plot of highest cited references (CR), highly productive authors (AU), and the top keywords associated by Scopus (ID) which have been extracted. We see that article written by Nonaka and Takeuchi: "Knowledge creating company" [1], Nonaka I.: "A dynamic theory of organizational knowledge creation" [47], and Davenport and Prushak: "Working knowledge: How organizations manage what they know" [6] have been cited the most among the other citations. These authors have influenced the research in this body of knowledge. Lin Y.C. is seen as the prominent contributor among all the other authors. It is seen that Lin Y.C. has largely researched with the construction industry addressing knowledge management, project management, and knowledge-based system. He has referred the work of Davenport T.H. and Prushak I to a large extent. Dingsyr T. has largely contributed to the areas of knowledge management, TK, software engineering, and knowledge engineering. Liu Z has prominently explored the TK space.

**Table 5** Authors, institutions, and countries with the most citations in the top 10

| R | Authors | TP | TC | Institution | TP | TC | Country | TP | TC |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Asheim B.T. | 2 | 1548 | University Of Oslo | 2 | 1548 | USA | 200 | 3447 |
| 2 | Zucker L.G. | 2 | 586 | University Of Lund | 2 | 1548 | Norway | 24 | 1262 |
| 3 | Demarest M. | 1 | 380 | University Of California | 7 | 796 | United Kingdom | 110 | 1068 |
| 4 | Bresnen M. | 1 | 290 | Norwegian University Of Science And Technology | 4 | 382 | Sweden | 44 | 1000 |
| 5 | Almeida P. | 1 | 266 | University Of Warwick | 2 | 290 | China | 141 | 682 |
| 6 | Mascitelli R. | 2 | 241 | Georgetown University | 1 | 266 | Canada | 31 | 337 |
| 7 | Bjørnson F.O. | 1 | 227 | Georgia State University | 5 | 256 | Italy | 20 | 331 |
| 8 | Lissoni F. | 1 | 216 | University Of Illinois At Urbana-Champaign | 2 | 252 | Switzerland | 20 | 315 |
| 9 | Boiral O. | 1 | 200 | Technology Perspectives | 2 | 241 | Spain | 31 | 242 |
| 10 | Hoetker G. | 1 | 198 | University Of Brescia | 1 | 216 | Australia | 29 | 205 |

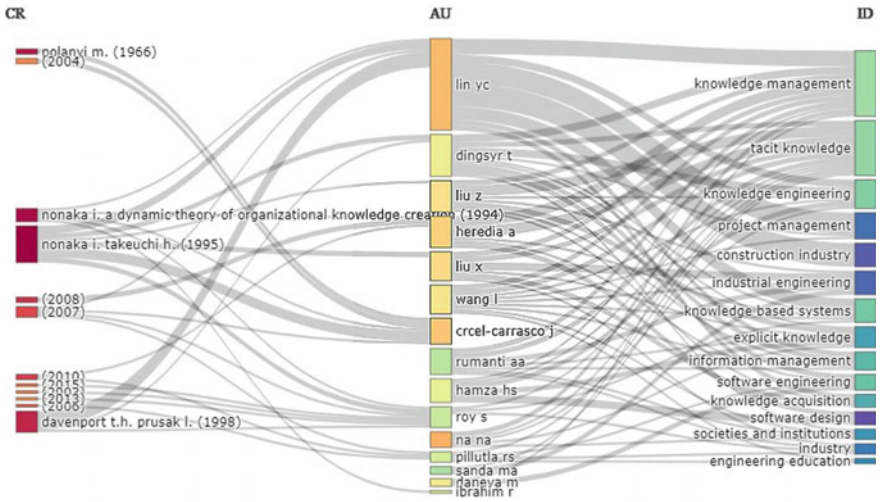


**Fig. 1** Relationship between Leading cited references, leading authors, and the top keywords

Knowledge management, TK, and knowledge engineering are the keywords in most of the top producing authors. In the set of articles extracted from Scopus for this study, there were 3870 different keywords in the keywords plus. In the figure, we see the top keywords used by the authors. The most relevant words are knowledge management, TK, and knowledge engineering. The dominance of these words gives an idea that the subject area is dealing a lot in TK management and knowledge-based systems. The trending topics of a 20-year span starting from 2000 extracted from Scopus tell an interesting story. Knowledge management was trending weakly till about 2007 and then started picking up to become prominent by 2012. Topics like knowledge engineering, information management started trending around 2008. Other topics that further picked up were knowledge acquisition, knowledge-based systems, explicit knowledge, and knowledge economy. Knowledge transfer and TK were trending at their peak during 2014. The topics that have been trending in the recent few years are human resource management, safety engineering, knowledge extraction, maintenance, technological development, Industry 4.0, etc. This indicates the new areas in which TK management is being studied.

## 4 Conclusions, Limitations, and Future Research

We conducted a thorough bibliometric analysis in the topic of "Tacit Knowledge Management in Engineering Industries" in this research. The use of bibliometric analysis assisted in the discovery of trends and developments in this field. Lin Y.C. is the database's most productive author. In addition, Asheim B.T. continues to be the most influential author, with the most citations, followed by Zucker L.G. and Demarest M. The main subjects of discussion in this bibliometric analysis are knowledge management, TK, and knowledge engineering. The most common source of publications is "Lecture Notes in Computer Science", followed by "Proceedings of the European Conference on Knowledge Management". The most productive countries are the United States and Norway, with National Taipei University of Technology in Taiwan producing the most papers. The bibliometric study's weakness is that it is dependent on citations and the quantity of papers. The quantity of published work is represented by the number of articles and citations; however, citations do not indicate quality. Papers with a low number of citations may not necessarily have a low scientific merit.

This study can be quite valuable for researchers who are just getting started in this field and want to start with a literature review. The analysis drew attention to the regions that were being investigated. It is worth mentioning that the research has primarily concentrated on project management, the construction sector, and software engineering; nevertheless, TK is present in every organization, and it would be worthwhile to investigate functions and sections of the engineering industry that have yet to be investigated. Employee knowledge sharing (which is not well explored in this body of knowledge) can be critical for firms to focus on in order to discover and address problems quickly and efficiently, which leads to innovation [48, 49]. The use of information technology to capture or even to digitalize TK does not seem to figure

prominently in this body of research. It can be researched further so that the industry can benefit in making the not so visible TK more visible [50]. Based on the trending topics, future researchers could study the areas which are evolving, like Industry 4.0, maintenance, and knowledge extraction. Presently, web-based technologies are being widely used by many organizations for interactions [51]. Researchers can concentrate on the components of knowledge sharing that can be accomplished using online platforms, as well as the implications for TK sharing. We have just looked at the commonly used Scopus database for bibliometric analysis; however, there are additional databases worth looking at, such as open-access journals. Other indexing databases, such as Web of Science and Google Scholar, can be used to undertake further analysis.

**Acknowledgements** We would like to acknowledge Symbiosis International University for providing us the access to the library.

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