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The Use of Statistical Process Control in Total Quality Management: A Bibliometric Analysis of Publication Performance and Trends

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Abstract. *Total Quality Management (TQM) has long been a focus of researchers due to its widespread application in enhancing the quality of all organizational processes. This paper conducts an extensive bibliometric analysis to uncover research patterns and trends in the scientific literature on the use of Statistical Process Control (SPC) tools within TQM. The bibliometric techniques employed provide descriptive and performance analyses, as well as mapping of the research field. Data was collected from the Scopus database with source-type journals of as many as 730 documents and analyzed using Bibliometrix on R software and VOSviewer. Statistical Process Control in Total Quality Management spans diverse fields like Medicine, Engineering, Business, Management and Accounting, Decision Sciences, and Nursing. Key publications appear in Pediatrics, Quality Progress, BMJ Open Quality, BMJ Quality and Safety, and TQM Magazine. Influential authors are Kaplan HC, Wang Z, and Wu Z. This field of research has been developed by researchers from countries such as the United States, United Kingdom, Canada, China and Taiwan. Cincinnati Children's Hospital Medical Center, Harvard Medical School, University of Washington, Johns Hopkins University, and McMaster University are the most relevant institutions. Recent studies emphasize quality improvement and statistical process control. This study benefits academics and practitioners investigating Statistical Process Control and offers a comprehensive overview of its role in Total Quality Management spanning the last 34 years. This research identifies the most influential authors, sources, affiliations, and countries in Statistical Process Control within Total Quality Management. Additionally, it illustrates the evolution of research in this field over time.*

Keywords: Quality, Total Quality Management, Statistical Process Control, Bibliometrics.

JEL Codes: E23, L15, M11,

1. Introduction

Total Quality Management (TQM) involves all levels and departments of an organization to improve product and service quality (Putri et al., 2017). Total quality management is a well-known area of study that has engaged numerous researchers in the past and present. The seven tools that can assist include check sheets, scatter diagrams, cause-and-effect diagrams, Pareto charts, flowcharts, histograms, and statistical

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process control with TQM (Heizer et al., 2020). One technique used in total quality management is statistical process control (SPC). SPC analyzes random samples from a process's output to determine if the items fall within a specified range. This method is extensively utilized to monitor and enhance the quality and efficiency both service and production processes. It encompasses various practices such as sample acceptance, statistical control, process monitoring, experimental design, and process capability analysis (Jacobs & Chase, 2018; Veiga et al., 2016).

TQM bibliometrics has been used to analyze the most widely discussed issues related to TQM in the service sector (Zhang et al., 2021), the literature on Industry 4.0, quality management, and TQM (Chiarini, 2020), and examine whether TQM is a fading trend in management and research (Lee & Hew, 2017). This study differs from others because it uses bibliometric analysis terms connected to the use of Statistical Process Control tools in Total Quality Management. Furthermore, the previous research explored by TQM trends was limited to the last 10 years (2006 - 2015), so this research also explores some research published in Scopus database up to now.

Total Quality Management (TQM) involves all company processes and activities to improve product and service quality (Khalil & Muneenam, 2021). TQM techniques are designed to continuously enhance and maintain the quality of products and processes by minimizing variability in production or service delivery and increasing efficiency, reliability, and overall quality (Al-Refaie et al., 2022). Total Quality Management (TQM) encompasses a comprehensive array of quality-centric business processes, including the design, development, control, maintenance, improvement, and assurance of products and services (Kaur et al., 2013). According to Heizer et al. (2020), seven critical TQM tools must be urgently implemented: 1) check sheets, scatter diagrams, and cause-and-effect diagrams for idea generation; 2) Pareto charts and process diagrams/flowcharts for data management; and 3) histograms and statistical process control (SPC) for problem identification. SPC is particularly crucial as it measures and corrects production variables to uphold standards. Veiga et al. (2016) emphasize the importance of SPC in monitoring a process's performance over time to verify compliance with predetermined standards by statistically analyzing variations, identifying "common causes of variation" that impact the process. SPC's graphical representation of changes is essential for determining whether a process is under control. Furthermore, there is a critical distinction between variable-based and attribute-based SPC (Haming & Nurnajamuddin, 2017). Jacobs & Chase (2018) clarify that variables are quality attributes measured in specific units such as weight, volume, or dimensions, while attributes are quality characteristics that either meet or fail to meet requirements. Immediate implementation of these tools and techniques is vital for maintaining and enhancing quality standards.

The publication of this topic is increasing every year, making it an opportunity and important for more comprehensive bibliometric studies to find the latest and address current problems with a large sample of research needed to design identifiable models and trends. Bibliometric analysis aims to (1) determine authors, sources, affiliations, and countries with the highest level of contribution, (2) identify publications with the highest contribution, and (3) determine the main literature on this topic. This research highlights the use and development of Statistical Process Control (SPC) in Total Quality Management (TQM) through a bibliometric study involving 730 research documents published between 1988 and 2022, obtained through searches in the Scopus database using specific keywords. The study will contribute to inform research trends, prioritize relevant topics, and support research policy decisions for SPC in TQM. Furthermore, it is scientifically valuable for evaluating the influence of research over time and predicting the direction and pattern of research in the future.

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2. Method

This quantitative descriptive study utilizes bibliometric analysis to uncover trends and research performance in scientific publications on the application of Statistical Process Control topics in Total Quality Management. Bibliometrics is a widely used method for exploring and analyzing extensive scientific data to assess the literature in a field, pinpoint knowledge gaps, generate new research ideas, and position scientists' intended contributions. (Janik et al., 2021).

The data collection required for this bibliometric analysis was taken from the Scopus database on August 8, 2022. This study uses Scopus because Anugerah et al. (2022) emphasize that Scopus stands as the most comprehensive resource for bibliometric analysis, providing extensive content, broad public visibility, and detailed profiles for every author, institution, and publication series. The keywords utilized in the data search were: (TITLE-ABS-KEY ("Total Quality Management" OR "TQM") AND TITLE-ABS-KEY ("Statistical Process Control" OR "SPC")) and produced 951 documents. Then, the data was filtered, namely based on source type. This research only used journals, so 730 documents were obtained that met the search criteria. The data is downloaded in Excel CSV format, which will later be used for bibliometric analysis. The data search strategy can be seen in the following flow diagram:

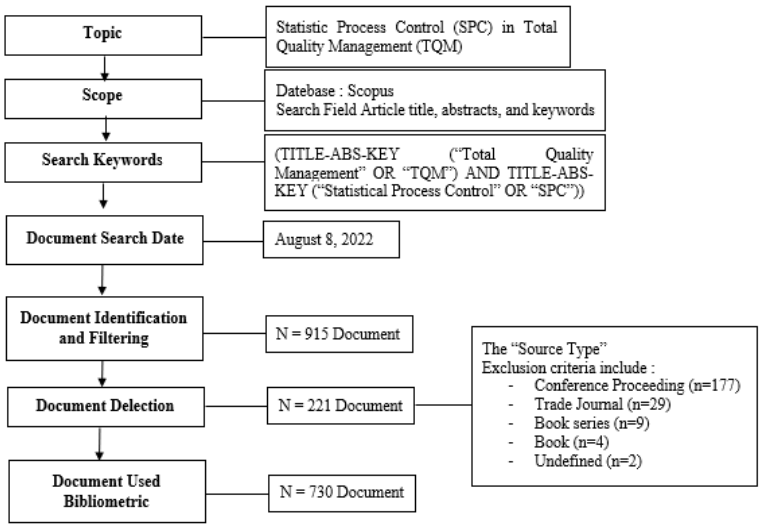


Fig. 1: Search strategy flowchart.

Source: Adopted from Anugerah et al. (2022)

This research utilizes two essential bibliometric analysis techniques to identify trends and evaluate research performance on Statistical Process Control topics in Total Quality Management. Firstly, descriptive and performance analysis examines document types, key subject areas, annual publication and citation counts, prolific authors and sources, affiliations, countries/regions, and highly cited articles. Secondly, network analysis maps research fields through author keyword co-occurrence networks, thematic maps, thematic evolution, and trending topics.

Data analysis in this study utilized VOSviewer software, the RStudio-Bibliometrix Package, and Tableau. The R-package Bibliometrix is a tool for conducting quantitative studies in bibliometrics and scientometrics (Corte et al., 2019). VOSviewer can generate journal, country, and publication maps based on networks (co-citation), keyword maps based on shared networks, and various other types of maps (Effendi et al., 2021). Tableau was used to illustrate publication and citation growth patterns and map the most productive countries.

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3. Results and Discussions

3.1. Descriptive Analysis and Bibliometric Performance

The research identified 730 works in the Scopus database on Statistical Process Control within Total Quality Management, including articles (674), conference papers (11), editorials (4), letters (8), notes (3), reviews (28), and short surveys (2). Most publications are in English (714), with others in Chinese (8), German (4), French (2), Danish (1), Hebrew (1), Spanish (1), and Undefined (1). These publications span various fields, primarily Medicine (359), Engineering (257), Business, Management, and Accounting (164), Decision Sciences (132), Nursing (77), and other fields.

The first Scopus publication on Statistical Process Control in Total Quality Management occurred in 1988 and continues to grow. Adams & Gavoor (1988) initial publication on Statistical Process Control in Total Quality Management was titled "Implementing a Company-Wide Quality Strategy," was the first entry found in the Scopus database. The study highlights the challenges, particularly in the US automotive industry, focusing on the balance between long-term and short-term performance measures to adapt to a dynamic market. The research details Rockwell Automotive initiated change by adopting a company-wide Total Quality Control strategy, emphasizing strategic planning, organizational climate, and popular techniques such as QFD, Taguchi Methods, SPC, and the Japanese approach. This research, conducted on Statistical Process Control in Total Quality Management, used document data published in Scopus for 34 years from 1988 to 2022. The annual publication trend can be shown in Figure 2. Growth in the number of publications published related to the use of Statistical Process Control in Total Quality Management in the first 20 years (1988-2007) was 276 publications, almost double the 454 publications in the last 14 years. The growth in publications on Statistical Process Control in Total Quality Management was most significant in 2021, with 62 publications. This shows that in the third quarter of 2022, there has been a slight decrease in the number of research conducted, namely 29 publications. However, let us notice the overall publication with the theme Statistical Process Control in Total Quality Management. The trend is increasing, which illustrates the growing research interest in this field.

Figure 2 also displays the citation impact of studies conducted each year. The bibliometric measure Mean Total Citations per Articles (MTCA) averages research citations from all Scopus-indexed publications (Suwarno et al., 2021). Since 1988-2007, MCTA has shown an increasing trend, while in 2008-2022 it has decreased. Based on the Mean Total Citations per Article (MTCA), the highest occurred in 2007, with an average of 70.75 citations. This shows that publications on Statistical Process Control in Total Quality Management in 2007 were more widely cited than in other years. Overall, the citation trend for Statistical Process Control in Total Quality Management has fluctuated with a decreasing trend. This can happen because research results have not generated many citations in recent years. After all, it takes time for research to have an impact. The number of publications (N) and MCTA in 1988–2022 can be seen in the following figure.

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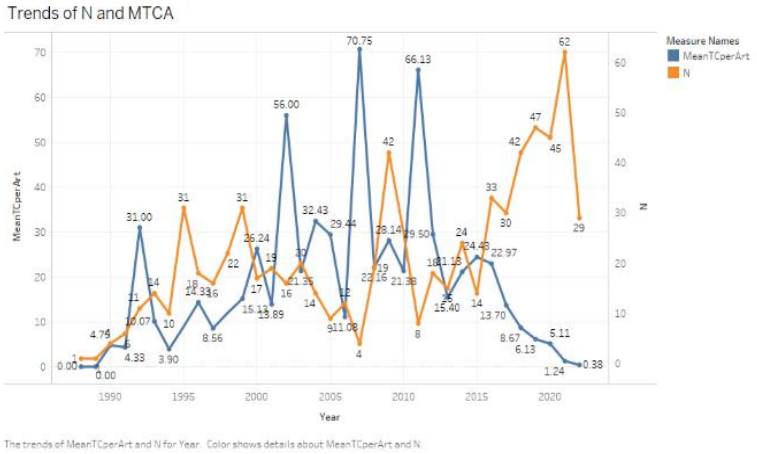


Fig. 2: Trends in Number of Publications (N) and Mean Total Citations per Article (MTCA).

Source: Data processing results (2022)

The number of publications related to Statistical Process Control in Total Quality Management has grown yearly. A total of 58 countries contributed to scientific publications regarding the use of Statistical Process Control in Total Quality Management, where the ten countries with the highest scientific publications are colored blue, as seen in Figure 3. In the blue color, it can be seen that the higher the country's contribution in publications related to Statistical Process Control in Total Quality Management, the darker the blue color produced on the map of that country. Country data is determined based on author affiliation. Based on the data obtained in Figure 3, it can be explained that the United States is the country in the first place, with the most significant contributor accounting for 412 publications (56.44%). The United Kingdom and Canada contributed 70 publications (9.59%) and 43 publications (5.89%), respectively, occupying second and third positions. China and Taiwan accounted for 29 publications (3.97%) and 13 (1.78%), respectively. India and Singapore contributed 11 publications (1.51%), while Australia contributed 10 (1.37%). And in the ninth and tenth place are Germany and Norway, which have the same contribution, namely 9 publications (1.23%).

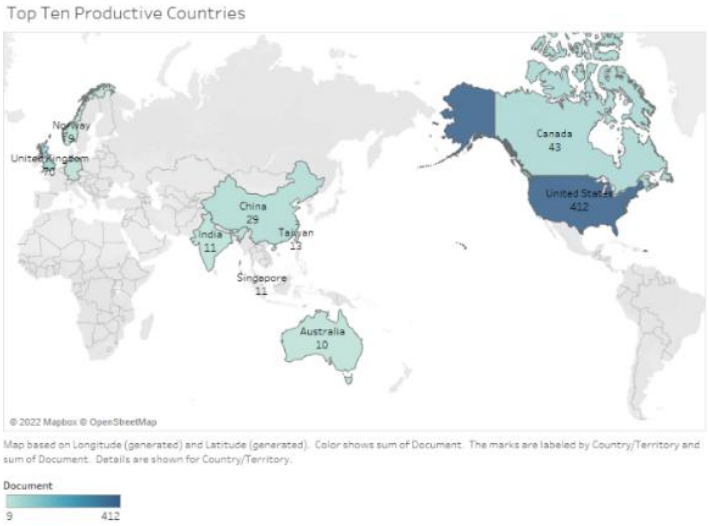


Fig. 3: Top ten most productive countries.

Source: Data processing results (2022)

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The sample used in this research was 730 studies related to Statistical Process Control in Total Quality Management published in 325 journals. The number of research published by each journal based on the level of relevance of the Statistical Process Control theme in Total Quality Management can be seen in Table 1. The top ten journals that received themes related to Statistical Process Control in Total Quality Management, namely 74 documents (10.14%) published in Pediatrics and 49 documents (6.71%) in Quality Progress, and the lowest was Computers and Industrial Engineering with 10 documents (1.37%). Other journals that publish research related to Statistical Process Control in Total Quality Management are BMS Open Quality, BMJ Quality and Safety, and TQM Magazine, each receiving 20 documents, Quality Engineering with 15 documents, International Journal of Production Research as many as 14 documents, as well as Production and Inventory Management Journal and Quality and Reliability Engineering International each with 13 documents. These journals are publication venues that accept research on Statistical Process Control in Total Quality Management. The greater the number of documents published in a journal, the more it can be said that the journal is relevant to the theme discussed, namely Statistical Process Control in Total Quality Management. Meanwhile, the most influential journals based on the total number of citations are Pediatrics, with 517 citations, and Journal of Quality Technology, with 224, while the other journals only have under 200 citations.

Table 1: Most relevant publication sources

Ranking	Publication Source	Article*	Publication Source	Article**
1	Pediatrics	74	Pediatrics	517
2	Quality Progress	49	Journal of Quality Technology	224
3	BMJ Open Quality	20	BMJ Quality and Safety	198
4	BMJ Quality and Safety	20	Quality & Safety in Health Care	167
5	TQM Magazine	20	Technometrics	159
6	Quality Engineering	15	JAMA	145
7	International Journal of Production Research	14	Journal of Pediatrics	136
8	Production and Inventory Management Journal	13	The New England Journal of Medicine	126
9	Quality and Reliability Engineering International	13	International Journal of Production Research	125
10	Computers and Industrial Engineering	10	Quality Progress	86

* Ranking according to the most relevant sources ** Ranking according to locally cited sources

Source: Data processing results (2022)

Our research has pinpointed the top 10 most prolific publications on Statistical Process Control (SPC) in Total Quality Management (TQM) (Table 1) and the 10 most cited articles (Table 2). Key bibliometric indicators, such as Local Citations and Global Citations, have been utilized to spotlight recent groundbreaking research (Suwarno et al., 2021). Global Citations account for the total citations a document has received within the Scopus database, while Local Citations refer to citations from publications specifically addressing SPC in TQM within the same database (Janik et al., 2021). This comprehensive analysis, conducted using Biblioshiny for Bibliometrix, identifies and ranks the most cited articles by both Local and Global Citations, revealing pivotal research within 730 documents.

On the other hand, the most influential publication based on Local Citations is an article by Johan Thor, Jonas Lundberg, Jakob Ask, Jesper Olsson, Cheryl Carli, Karin Pukk Härenstam, and Mats Brommels.

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Published in 2007 in Quality and Safety in Health Care, their article, "Application of Statistical Process Control in Healthcare Improvement: A Systematic Review," has received 26 citations. This systematic review highlights the application of control charts, a fundamental SPC tool, in improving healthcare quality. The findings underscore SPC as a versatile tool aiding diverse stakeholders in managing healthcare changes and enhancing patient health outcomes.

Table 2: Most influential articles

Ranking	Local Citations	Global Citations	LC/GC Ratio (%)	Local Citations
1	Critical success factors for the successful implementation of six sigma projects in organisations (Coronado & Antony, 2002)	0	427	0,00
2	The run chart: a simple analytical tool for learning from variation in healthcare processes (Perla et al., 2011)	18	272	6,62
3	Application of statistical process control in healthcare improvement: Systematic review (Thor et al., 2007)	26	253	10,28
4	Behind the learning curve: Linking learning activities to waste reduction (Lapre´ et al., 2000)	1	234	0,43
5	Successful change programs begin with results (Schaffer & Thomson, 1992)	0	220	0,00
6	Systematic review of the application of quality improvement methodologies from the manufacturing industry to surgical healthcare (Nicolay et al., 2012)	8	203	3,94
7	Total quality management: an empirical test for mediation effect (Ho et al., 2001)	3	144	2,08
8	Explanation and elaboration of the SQUIRE (Standards for Quality Improvement Reporting Excellence) Guidelines, V.2.0: Examples of SQUIRE elements in the healthcare improvement literature (Goodman et al., 2016)	6	143	4,20
9	An enhanced adaptive CUSUM control chart (Wu et al., 2009)	0	137	0,00
10	Rooming-in to treat neonatal abstinence syndrome: improved family-centered care at lower cost (Holmes et al., 2016)	0	133	0,00

*Ranking based on global citations

Source: Data processing results (2022)

Total Quality Management (TQM) is a management approach that aims to improve the quality of products and services in various industries. Research shows that the successful implementation of TQM depends on several important factors, such as a solid work team, adequate training, linkage to business strategy, understanding customer needs, and management support (Coronado & Antony, 2002). In the healthcare sector, statistical process control (SPC) tools have proven to be highly effective in managing process changes, improving patient outcomes, and detecting variations in infection rates (Thor et al., 2007). Run charts also play an essential role in integrating process variations and improving the quality of care (Perla et al., 2011).

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Implementing TQM in manufacturing, service, and health industries shows that quality control is critical to improving operational efficiency and performance (Lapre´ et al., 2000; Schaffer & Thomson, 1992). Lean, Six Sigma, and TQM methodologies in the surgical healthcare sector have reduced errors, infections, and drug costs and improved patient care quality (Nicolay et al., 2012). Core TQM practices are essential in converting the effects of supporting TQM practices into improved quality performance, making quality control crucial to ensure all aspects, from the production process to supplier management, are well managed to achieve optimal quality performance (Ho et al., 2001).

Studies in various industries show that TQM focuses on improving processes and overall quality (Goodman et al., 2016). Using CUSUM control charts in statistical process control helps enhance the quality of products, operational efficiency, and process control in various sectors, including manufacturing and technology (Wu et al., 2009). Implementing rooming-in practices through a Quality Improvement (QI) approach in the health service sector also shows improved quality management in caring for babies with Neonatal Abstinence Syndrome (Holmes et al., 2016). Overall, TQM and statistical process control are essential in improving the quality of products and services in various industries, ensuring operational efficiency, reducing defects, and increasing customer satisfaction.

Figure 4 shows the most relevant institutions in publishing Statistical Process Control research in Total Quality Management. These top ten affiliates are in the United States and Canada. Affiliates originating from the United States are Cincinnati Children's Hospital Medical Center with 53 articles (7.26%), Harvard Medical School with 47 articles (6.44%), University of Washington with 44 articles (6.03%), Johns Hopkins University with 37 articles (5.07%), Dartmouth-Hitchcock Medical Center with 33 articles (4.52%), and Nationwide Children's Hospital with 32 articles (4.38%). Next, affiliates from Canada were carried out by McMaster University with 34 articles (4.66%) and the University of Toronto with 31 articles (4.25%). The rest of the affiliates only contributed under 30 articles. Thus, it can be seen that Cincinnati Children's Hospital Medical Center is an affiliate with the most contributions of research articles using the topic of Statistical Process Control in Total Quality Management compared to other affiliates.

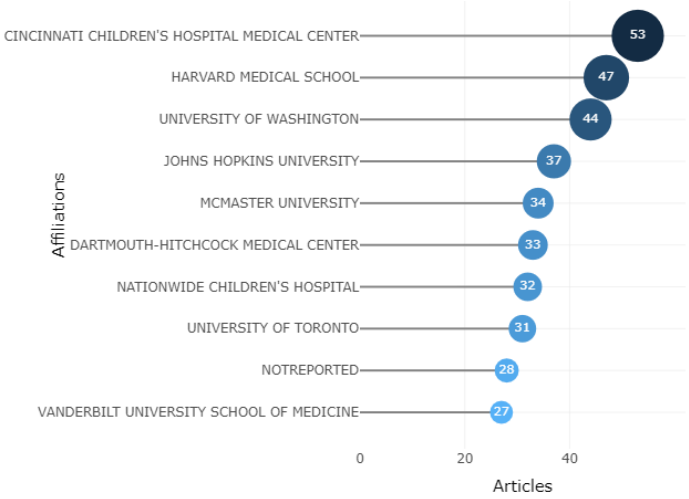


Fig. 4: Top ten most relevant affiliates.

Source: Data processing results (2022)

Authors who have published their writings are sorted according to the resulting impact based on the h-index, where in the top ten authors, this h-index value ranges from 4 to 7. The most significant statistical process control researchers in overall quality management are included in Table 3. Kaplan HC stands out as the most influential, boasting an h-index and g-index of 7, supported by 7 publications and 385 citations,

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making him both the most influential and productive writer in this field. Following are Wang Z and Wu Z, ranked second and third with an h-index value of 6 from their 6 publications each. Additionally, Antony J, Guh R-S, Gupta M, Li Z, Poots AJ, and Provost LP hold an h-index of 4 with 4 publications, while JR has an h-index of 4 with 6 publications.

Table 3: Most influential authors

Ranking	Authors	h_index	g_index	m_index	TC	NP	PY_start
1	Kaplan HC	7	7	0,583	385	7	2011
2	Wang Z	6	6	0,429	310	6	2009
3	Wu Z	6	6	0,429	292	6	2009
4	Antony J	4	4	0,167	221	4	1999
5	Guh R-S	4	4	0,167	302	4	1999
6	Gupta M	4	4	0,667	52	4	2017
7	JR	4	6	0,133	100	6	1993
8	Li Z	4	4	0,308	162	4	2010
9	Poots AJ	4	4	0,364	51	4	2012
10	Provost LP	4	4	0,148	356	4	1996

Total Citations (TC), Number of Publications (NP), Initial Year of Publication (PY_start)

Source: Data processing results (2022)

3.2. Literature Research Field Mapping Analysis

Identification of the main research topic on Statistical Process Control in Total Quality Management begins with the analysis of the co-occurrence network structure based on author keywords. A keyword co-occurrence network is a network of author keywords in the same publication that are strongly related and can indicate the core of a research paper (Su & Lee, 2010). Keyword co-occurrence networks study literature keyword connections to understand scientific/technical subject knowledge (Radhakrishnan et al., 2017). Only keywords that appeared at least three times were considered to avoid less important topics and reveal more obvious notions. The author utilized 1234 keywords, but 75 were relevant and formed the network in Figure 5. Circle size shows keyword frequency in Statistical Process Control literature in Total Quality Management. Larger circles indicate authors' frequent keyword selection. Lines linking keywords show their co-occurrences in publications. Significant line widths indicate more co-occurrences (Janik et al., 2021). Word groups are shown by color. The analysis found 12 groupings reflecting the key subtopics of Total Quality Management Statistical Process Control research. Based on the analysis, the words marked with the highest total link strength are statistical process control, quality improvement, quality control, spc, total quality management, quality, TQM, control charts, six sigma, and control chart.

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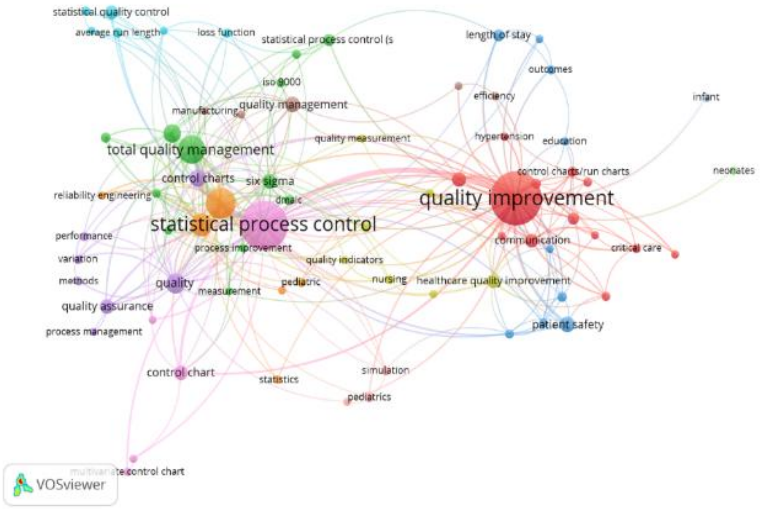


Fig. 5: Co-occurrence network based on author's keywords.

Source: Data processing results (2022)

Groups representing research subtopics in the Statistical Process Control literature in Total Quality Management include: Cluster 1 (13 items): ambulatory care, communication, control charts/run charts, critical care, emergency department, hand-off, hospital medicine, hypertension, pediatrics, patient satisfaction, primary care, quality improvement, sustainability. Cluster 2 (12 items): continuous improvement, dmaic, iso 9000, measurement, process improvement, qfd, six sigma, statistical process control (spc), taguchi methods, total quality management, total quality management (tqm), tqm. Cluster 3 (9 items): education, health services research, implementation science, lean, length of stay, outcomes, patient safety, PDSA, quality improvement methodologies. Cluster 4 (7 items): continuous quality improvement, control charts-run charts, healthcare quality improvement, nursing, quality indicators, quality measurement, statistical process control charts. Cluster 5 (7 items): control chats, methods, performance, process management, quality, quality assurance, variation. Cluster 6 (6 items): average run length, cusum chart, loss function, multivariate quality control, shewhart chart, statistical quality control. Cluster 7 (6 items): pediatric, quality control, reliability engineering, short peripheral catheter, spc, statistics. Cluster 8 (5 items): case study, efficiency, hospitals, manufacturing, quality management. Cluster 9 (5 items): control chart, economic design, multivariate control chart, pattern recognition, statistical process control. Cluster 10 (3 items): cost, pediatrics, simulation. Cluster 11 (1 item): neonates. Cluster 12 (1 item): infant. The above findings demonstrate the variety of keywords authors use, reflecting the multidimensional nature of the Statistical Process Control concept within Total Quality Management.

Figure 6 presents a thematic map constructed using the author's keywords, emphasizing specific clusters and their interconnections. The effectiveness of the cluster design in representing critical research problems increases with the strength of these connections (Yu & Justicia, 2020). This map elucidates the conceptual structure of the topic, classifying themes into four quadrants: Motor themes, Niche themes, Basic themes, and Emerging or Disappearing themes (Cobo et al., 2011). Motor themes, located in the upper right quadrant, exhibit high centrality and density, signifying their advanced development and crucial importance to the research field (Corte et al., 2019). This quadrant includes cluster 2, which encompasses quality improvement, patient safety, and primary care. Niche themes, found in the upper left quadrant, are highly developed internally but have limited external significance, indicating strong internal coherence but minimal impact on the broader field (Corte et al., 2019). This quadrant includes cluster 1 (multivariate control chart), cluster 4 (pediatric), and cluster 6 (process management). Emerging or declining themes occupy the lower left

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quadrant, characterized by low centrality and density, reflecting their weak and marginal development (Corte et al., 2019). This quadrant includes cluster 7 (statistical quality control) and cluster 5 (infant). Lastly, fundamental and transversal themes are located in the lower right quadrant, marked by high centrality but low density, indicating their broad relevance and fundamental role across various research areas (Corte et al., 2019). This quadrant includes cluster 3 (statistical process control), which covers statistical process control, quality control, and total quality management.

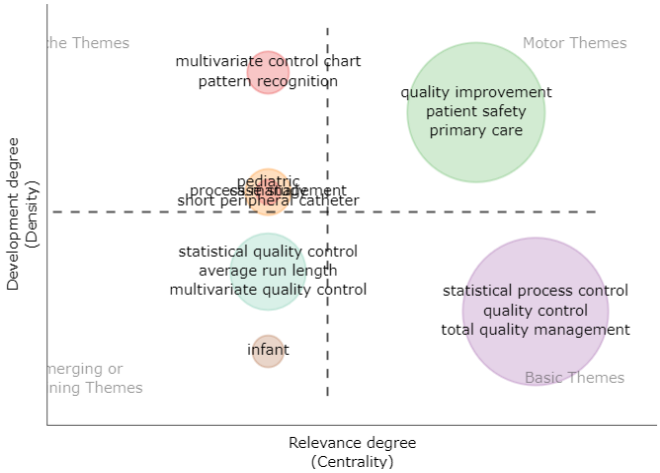


Fig. 6: Thematic map based on the author's keywords.

Source: Data processing results (2022)

Trend topics are also part of this research. Trend topics refer to research topics that are currently popular (Murillo-Vargas et al., 2020). Figure 7 provides a general overview of topic developments over time, categorized by year based on the results of the author's keyword analysis related to the application of Statistical Process Control in Total Quality Management from 2003 to 2022. According to this figure, 19 topics need to be considered over the past 20 years. The image also reveals which topics have been consistently used or have emerged recently. The appearance of these topics is correlated with the frequency of research words related to Statistical Process Control in Total Quality Management. The size of the circle in the image corresponds to the frequency of words used for a particular topic, with the position of the circle indicating the topic's prevalence in research for a specific year. The horizontal line of the circle indicates the period when the topic was extensively researched. Topics that were commonly researched in 2021 include pediatrics and control charts/run charts. On the other hand, quality improvement and statistical process control have been frequently researched over the past 20 years. Quality improvement was the most researched topic from 2016 to 2020 and became the most popular topic with a frequency of 124 in 2019, alongside patient safety and primary care. However, the frequency of these two topics was still lower compared to quality improvement. Statistical process control held the second position, being widely researched from 2007 to 2016 and becoming the most popular topic with a frequency of 106 in 2009, coinciding with quality control and SPC. Nonetheless, the frequencies of these two topics were lower.

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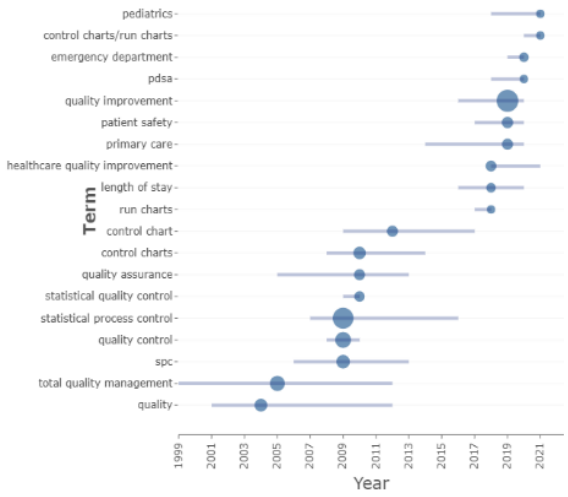


Fig. 7: Topic trends of the last 20 years.

Source: Data processing results (2022)

The next step is a thematic evolution analysis representing research sub-topics in the Statistical Process Control literature in Total Quality Management. Thematic evolution, as generated by R Bibliometrix Biblioshiny, portrays the progression and transformation of keyword clusters across different periods (Hermes & Riedl, 2021). This analysis uses Sankey Diagrams. Sankey diagrams demonstrate related themes that have emerged over time, where each box on the map represents a subject, and its size corresponds to its frequency of appearance (Abhishek & Srivastava, 2021; Aria et al., 2020). The analysis carried out in this research was over 1988-2004, 2005-2017, 2018-2022. The range's years change due to a large rise of publications in recent years. Results are shown in Figure 8.

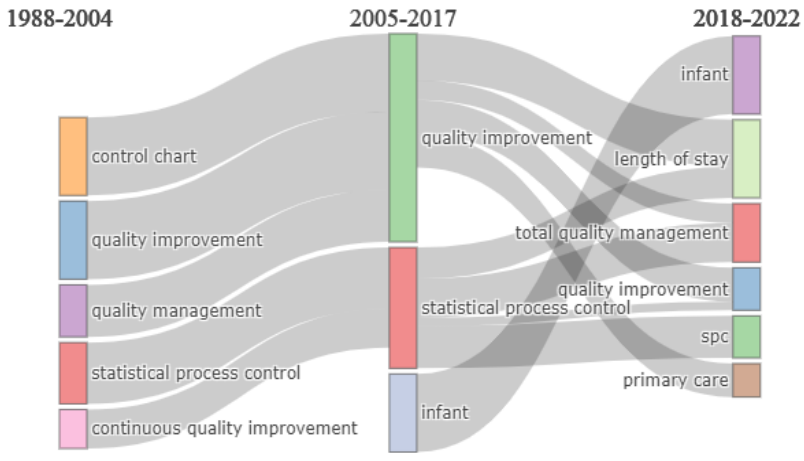


Fig. 8: Thematic evolution based on the author's keywords.

Source: Data processing results (2022)

Figure 8 illustrates that during the initial phase of exploring the Statistical Process Control concept in Total Quality Management, research concentrated on various sub-topics: control charts, quality improvement, quality management, statistical process control, and continuous quality improvement. In the subsequent period (2005-2017), several topics evolved. Control charts, quality improvement, and quality

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management merged into quality improvement; statistical process control and continuous quality improvement merged into statistical process control. A new topic, infants, emerged during this period. The present research is centered on infants, length of stay, total quality management, quality improvement, SPC, and primary care. The evolution of the Statistical Process Control topic in Total Quality Management indicates a growing interest from researchers across different fields. Statistical process control emerged between 1988-2004 and gained popularity from 2005-2017, aligning with the quality improvement topic.

4. Conclusions

The research findings suggest that the Statistical Process Control literature in Total Quality Management spans various fields, predominantly Medicine, Engineering, Business, Management, Accounting, Decision Sciences, and Nursing. Key publications include Pediatrics, Quality Progress, BMJ Open Quality, BMJ Quality and Safety, and TQM Magazine. Over time, there has been a rise in publications on this topic, but its citation structure has experienced fluctuations, indicating a decreasing trend. The most globally cited article is "Critical Success Factors for the Successful Implementation of Six Sigma Projects in Organizations", while the locally cited article is "Application of Statistical Process Control in Healthcare Improvement: Systematic Review". Influential authors include Kaplan HC, Wang Z, and Wu Z. Researchers from the United States, United Kingdom, Canada, China, and Taiwan have significantly contributed to this field. Noteworthy institutions include Cincinnati Children's Hospital Medical Center, Harvard Medical School, University of Washington, Johns Hopkins University, and McMaster University.

This study explores research findings through field mapping analysis. Co-occurrence network analysis highlights prevalent themes such as statistical process control, quality improvement, SPC, total quality management, TQM, control charts, six sigma, and quality in the literature. Over the past two decades, quality improvement and statistical process control have been popular research areas. Thematic evolution analysis shows an early focus on control charts, quality improvement, quality management, statistical process control, and continuous quality improvement in exploring Statistical Process Control in Total Quality Management. In subsequent years, these themes merged and transformed, with 'infant' emerging as a new area of interest.

This study utilizes bibliometric methods to present academics and professionals with a comprehensive overview of Statistical Process Control in Total Quality Management over the past 34 years. It lays the groundwork for future research in this area. Despite offering a thorough analysis, the study has its constraints. It exclusively depends on the Scopus database and concentrates on articles for bibliometric analysis within the Statistical Process Control literature in Total Quality Management. It is recommended that future research considers databases like WoS and Google Scholar for further exploration. Moreover, upcoming studies could delve into various document types beyond articles, such as conference papers, reviews, and other forms of documentation.

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