Bibliometric Analysis on Quality Management in the Oil Sector

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Abstract

The oil sector represents approximately five percent of the global economy. Approximately 33% of the world’s energy consumption is derived from oil. Given that oil is a globally traded commodity, its processing must adhere to internationally recognized quality standards. The overarching objective of this research was to ascertain, through a bibliometric analysis of the field of quality management in the oil sector, the state of scientific research published during the period from 2000 to 2020. A total of 59 documents were obtained through an equation defined in the Scopus database and subsequently reviewed. The research demonstrates the quantity and structure of the indicators. The study defined six research groups and four periods within the specified time frame. An evolution in the processes was identified, encompassing both technical and administrative areas and integrating the supply and production chain. The offshore and onshore operational areas were identified as a prominent focus, encompassing maintenance and process control in the construction of wells, surface facilities, and production. Additionally, the refining phases and environmental impact were considered. The necessity for incorporating the commercialization and transportation phase, as well as the exploratory phase, was also discerned. Notably, there was a dearth of research elites on the subject, which presents an opportunity to explore avenues in other areas of the industry and beyond.

Keywords: Bibliometric Analysis, Quality Management, Oil Sector

INTRODUCTION

In the intricate and multifaceted oil industry, factors such as reliability, efficiency, and safety are of paramount importance. It is essential that the standards established for the exploration, production, refining, and distribution processes guarantee the proper functioning of the system as a whole. In this regard, Pineda (2020) indicates that quality management is based on a “set of policies, objectives, strategies, actions, and procedures aimed at guaranteeing, controlling, and promoting quality in all areas, to ensure progressive improvement, emphasizing mainly opportunities and strengths” (p. 10).

In this context, quality management has emerged as a means of standardizing and guaranteeing the production and service management offered by various industries. Organizations that implement a Quality Management System (QMS) tend to achieve notable outcomes, including enhanced efficiency, greater process control, reduced costs, and facilitated expansion and growth. For this reason, the paper details the contribution of authors on the topic of Quality management in the Oil Sector.

LITERATURE REVIEW

The importance of QMS is evidenced by findings from research conducted by Arribas & Martínez (2018), Galvez et al. (2016), Fernández et al. (2016), Fontalvo et al. (2018), Matorera (2018), and Taylor et al. (2020), Zarei et al. (2019), Vargová et al. (2020), Sokolov et al. (2019), Alwerfalli et al. (2016), Keenan & Rostami (2021), Ćwiklicki et al. (2020) have also addressed the impact of QMS on educational institutions, industries, and different organizations. Hernandez et al. (2018) define QMS as a strategy to enhance business competitiveness and view the organization as a set of interrelated processes with the overarching objective of achieving customer satisfaction.
In particular, the theorist Deming (2009) defines quality as that predictable degree of uniformity and reliability at a low cost. For this reason, there is currently a tendency to incorporate it as a constant goal in every productive and organizational process. In accordance with this concept, the industry, in its various sectors, strives to oversee quality management in each of its constituent departments to the greatest extent possible.

It can be reasonably asserted that the oil industry worldwide is no exception to the implementation of a quality management system (QMS). This is primarily due to the fact that, in recent times, these companies have endeavored to offer high-quality products and services as a strategy that allows them to enhance their competitiveness and recognition, both nationally and internationally (Andara et al., 2020). In response to increased energy demand, these organizations have experienced significant growth in recent years.

For this reason, the implementation of a quality management system (QMS) is of paramount importance for oil companies in the Latin American region. These frameworks are indispensable for ensuring the consistent delivery of high-quality products and services across a range of industries, including the oil industry. The extraction and export of oil contribute significantly to the economies of several countries. Records from the Organization of Petroleum Exporting Countries (OPEC, 2022) indicate that this accounts for a 7% share in South and Central America, after the Middle East, North America, Europe, Asia, and Oceania (Association of the Hydrocarbon Industry of Ecuador [AIHE, 2022]).

The most commonly used QMS standards worldwide are ISO 9001 and API Q1. These were developed by the International Organization for Standardization (ISO) and provide a generic set of guidelines to be established in various industries. These standards place particular emphasis on process focus, customer focus, and continuous improvement. A considerable number of oil companies have implemented the ISO 9001 standard with the objective of enhancing operational efficiency, customer satisfaction, and overall quality performance.

Moreover, the American Petroleum Institute (API) developed API Q1, a standard specifically designed for the oil and gas industry. API Q1 incorporates elements of ISO 9001, but includes industry-specific requirements to address the unique challenges and complexities inherent to the sector. The emphasis is placed on risk management, change control, and the implementation of rigorous documentation procedures to guarantee process reliability and safety (Normas API: API Q1, API Q2. Industria del petróleo y gas natural, 2022).

In the context of the petroleum industry, compliance with the requirements set out in API Q1 is frequently a prerequisite for the certification of a given product. Both ISO 9001 and API Q1 require organizations to establish quality policies, conduct regular internal audits, and undergo external audits by accredited certification bodies. Moreover, Six Sigma and Total Quality Management (TQM) methodologies are frequently integrated into Quality Management System (QMS) approaches within the industry. Six Sigma aims to minimize defects and variations in processes, thereby enhancing overall efficiency. TQM, on the other hand, emphasizes continuous improvement through the active involvement of all employees (Egea, 2016).

These methodologies are particularly pertinent in the context of the oil sector, where precision, safety, and reliability are of paramount importance. Moreover, health, safety, and environmental (HSE) management systems are of paramount importance for oil companies. The ISO 45001 standard, which is concerned with occupational health and safety, and the ISO 14001 standard, which is focused on environmental management, have both been widely adopted within the industry. Compliance with these standards ensures that oil companies prioritize the well-being of their workforce, mitigate environmental impact, and comply with regulatory requirements.

In conclusion, ISO 9001 and API Q1 are the most widely adopted quality management system standards in industry, including the oil sector, with the objective of ensuring the consistent delivery of high-quality products and services. The integration of methodologies such as Six Sigma and TQM serves to enhance the precision and efficiency of processes. Moreover, HSE management systems, exemplified by ISO 45001 and ISO 14001, are indispensable for oil companies to safeguard their workforce, mitigate environmental impact, and adhere to regulations (Blasco et al., 2019). These QMS frameworks collectively contribute to the industry's commitment to quality, safety, and environmental responsibility, which are essential pillars in the dynamic and challenging landscape of the oil sector.
Each country within the region faces its own unique challenges and priorities. However, there is a common recognition of the importance of adhering to international standards, with ISO 9001 being the predominant framework. Brazil, another significant actor in the Latin American oil sector, has progressively acknowledged the value of quality management systems in the pursuit of sustainable development and global competitiveness. The country has witnessed a growing adoption of the ISO 9001 standard, which reflects a commitment to quality management throughout the petroleum value chain (Morris et al., 2013).

In Brazil, the quality management system (QMS) is a crucial tool for ensuring compliance with environmental regulations, promoting social responsibility, and fostering innovation. The ISO 14001 standard, which addresses environmental management, is also of significance in light of the heightened emphasis on sustainable practices within the Brazilian oil industry. Adherence to these standards enables Brazilian oil companies to enhance their reputation, mitigate environmental impact, and align their practices with evolving stakeholder expectations.

Another country in the region is Colombia. Despite its relatively limited dependence on oil compared to other regional counterparts, it has witnessed a notable expansion of its presence in the oil and gas industry. The oil sector in the country is becoming increasingly aware of the significance of the QMS in guaranteeing product quality, operational efficiency, and regulatory compliance. The ISO 9001 standard is a valuable tool for Colombian oil companies, as it allows for the standardization of processes, an improvement in customer satisfaction, and the facilitation of international trade. Furthermore, the relevance of ISO 14001 is reinforced by the Colombian government's growing emphasis on environmental sustainability (Colombian Association of Petroleum Engineers [ACIPET, 2023]). The incorporation of SGC into the operational framework of Colombian oil companies enables them to effectively navigate the complexities of the market.

Similarly, Argentina, which is in the process of developing its oil industry, underscores the significance of a quality management system in establishing the groundwork for sustainable growth. The ISO 9001 standard is fundamental to providing a systematic approach to quality management, which enables Argentine oil companies to streamline processes and optimize resource utilization. As the industry matures, adherence to the QMS becomes a critical factor in ensuring competitiveness and meeting the expectations of both domestic and international stakeholders (Agenda Nacional de Promoción de la Investigación, el Desarrollo Tecnológico y la Innovación de la Argentina, 2019). Argentina's oil sector has the potential to enhance operational efficiency and align with global sustainability goals by leveraging ISO 50001, which focuses on energy management.

In Venezuela, with its considerable oil reserves, the significance of the SGC cannot be overstated. The country's oil industry is confronted with significant challenges pertaining to political instability and economic fluctuations. It is of the utmost importance for Venezuelan oil companies to implement the ISO 9001 standard in order to overcome the aforementioned uncertainties. The ISO 9001 standard, which places an emphasis on quality management principles, provides a structured framework for organizations to improve efficiency, mitigate risks, and ensure the consistent delivery of high-quality products and services (Prieto, 2016). For Venezuela, alignment with international standards is not only a matter of operational excellence; it is also a means of attracting foreign investment and maintaining a competitive advantage in the global market.

In light of the aforementioned considerations, the significance of a quality management system (QMS) for oil companies in the Latin American region is manifold. As the Latin American oil industry continues to evolve, the integration of robust quality management systems constitutes an indispensable component of its resilience, competitiveness, and capacity to navigate the dynamic global energy landscape (Rivera, 2015).

In this regard, research has been conducted with the objective of providing solutions to the various challenges that have emerged during the implementation of these systems. The presentation and solutions have been documented in articles published in scientific journals at the national and international levels. Similarly, an initial bibliographic search revealed a substantial number of historical documents.

Given the significance of QMS in the oil industry and the necessity to comprehend the trends and investigative approaches developed in the sector in recent years, this research proposes a bibliometric analysis, which is a valuable technique for measuring the quantity and quality of scientific publications on a specific topic (Estrella...
& Lastra, 2018). A review of global research on quality management systems (QMS) in the hydrocarbon industry was conducted. The review encompassed methodologies, innovations, descriptions of already standardized processes, and discussions of QMS implementations in service and manufacturing procedures.

**METHODOLOGY**

Bibliometric analysis is a quantitative research method that enables the identification and evaluation of research trends and patterns within a specific disciplinary field. It synthesizes the available evidence on the subject, providing insights into the evolution of research within that field. In the specific case of the research presented, the overarching objective was: The objective of this bibliometric analysis is to ascertain the state of scientific research published in the field of quality management in the oil sector between the years 2000 and 2020.

To achieve the proposed objective, a search was conducted in the Scopus database. The database was selected for its interdisciplinary scope and comprehensive coverage of authors, citations, research institutes, journals, and years. It is also one of the most prominent databases in terms of the number of citations generated by the journals in which articles are published.

In order to conduct the search, inclusion and exclusion criteria were established (see Table 1). A total of 72 records of scientific articles that met the majority of the stipulated standards were reviewed, with the exception of 13 articles that, upon further analysis, were found to pertain to the topic of QMS in companies, but not specifically in the oil sector. Accordingly, the search equation was modified, and the bibliometric analysis was conducted with 59 documents.

<table>
<thead>
<tr>
<th>Inclusion criteria</th>
<th>Exclusion criteria</th>
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<tr>
<td>All scientific articles published in the Scopus database that contained the keywords: quality management, quality, quality management systems, petroleum, petroleum industry, hydrocarbons, and hydrocarbon industry.</td>
<td>Scientific articles published in a database other than Scopus</td>
</tr>
<tr>
<td>Scientific articles published in the Scopus database in the period from 2000 to 2020</td>
<td>Scientific articles published before the year 2000 or after the year 2020.</td>
</tr>
<tr>
<td>Scientific articles published in all languages</td>
<td>Documents related to the topic of quality and quality management systems of other industries other than oil</td>
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Once the documents that constituted the basis of the research were selected, we proceeded with the construction of the database. Only the information that was necessary for the study was included in the database: authors, title, journal, citations, DOI, affiliations, abstract, keywords, and type of document. From the data included in the database, indicators related to scientific output in this field were calculated over time and in relation to countries, languages, research institutions, authors, journals, and trends.

Ultimately, the VOSviewer software was employed to construct a map of co-occurrences, co-authorships, and history, which enabled the delineation of group formations in accordance with the identified trends and the associations between potential research groups and the evolution of approaches over time.

**RESULT AND FINDINGS**

As defined by Górriz & Casterá (2018), bibliometrics is a subfield of scientometrics that employs mathematical and statistical techniques to examine all forms of scientific literature and the individuals who produce it, with the aim of elucidating and analyzing scientific activity. Once the corpus or portfolio of documents was obtained, the indicators of publications by year, publications by country, language, type of publication, citation and authors, topics, and trends were recorded.

Figure 1 presents a graph illustrating the number of publications on quality management systems (QMS) in the oil industry on an annual basis from 2000 to 2020. As illustrated in the graph, the number of publications ranges from a minimum of one to a maximum of six. This final figure was attained in 2016. The reason for the observed increase or decrease in publications is unclear; however, it can be postulated that the introduction of the ISO 9000:2015 standard may have contributed to the elevated number of publications in 2016.
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Figure 1. Number of publications on QMS in the oil industry per year

Figure 2 shows the number of publications on QMS in the oil industry by country. The five leading countries in which research related to the topic of QMS in the oil industry has been developed and has been published in Scopus journals, were the United States with eight publications, followed by the United Kingdom with six, then Russia with five, China with four and Germany with three publications.

Figure 2. Publications by country

In this context, research conducted in the United States has primarily been published in documents issued at symposia and conferences. These studies have largely focused on the industrial oil process, rather than on the services sector, including the energy sector (Ekici & White, 2018), the construction of oil pipelines (Gould et al., 2016), coiled tubing wells (Ginest, 2016), production and drilling equipment (Clevenger et al., 2015), and heater and boiler emissions control (Corbit, 2012). Additionally, studies have been conducted on lubricants (Hamaguchi, 2004).

Similarly, the majority of publications from the Russian Federation originate from the oil industry and were published within the last four years. These publications are directly related to the quality management process, specifically in pipeline transportation (Lyapin and Timofeev, 2020), the control of accidents in pipeline transportation facilities (Slepnev & Maksimenko, 2019), oil and gas companies (Andreeva et al., 2018), drilling fluids (Kershenaubam, 2017), and long-distance transportation in the construction of oil pipelines (Vasoliev & Lange, 2014).

In this regard, research publications from China were more prevalent in scientific journals than in publications generated from events. Their research on quality management systems (QMS) is more detailed. For example, Zhang et al. (2014) conducted research on efficient welding quality control in an offshore oil field, while Sieling...
and Fackert (2013) conducted research on hot and cold rolled products. Liang (2008) also conducted research on a long-distance oil pipeline.

The research from Germany was related to research from other countries, as is the case with the aforementioned study on hot and cold rolled products (Sieling & Fackert, 2013), which Scopus considered to be research from both countries. Additionally, research has been conducted in Germany on the reduction of emissions and its impact on the industry (Schaaf & Schoeckle, 2010), published in the American Society of Mechanical Engineers.

Similarly, the majority of publications were in English, as illustrated in Figure 3, with over 50 publications and a minimal number in Russian, with only one publication in Chinese (Mandarin). It is noteworthy that there is a paucity of documents in Spanish, despite the existence of substantial oil companies in Latin American countries. However, further investigation could ascertain whether this is also the case for research in the area of QMS, as evidenced by a study on quality management and organizational performance in the Venezuelan oil industry. (Morris et al., 2013).

![Figure 3. Number of publications per language](image)

As illustrated in Figure 4, the majority of the publications retrieved through the proposed search equation originate primarily from two sources: scientific articles and session papers from congresses, conferences, symposia, and exhibitions. Additionally, three articles were sourced from the notes of gas pipeline journals, conference reviews, book chapters, and a single review.

The results of the study indicate that research on quality management systems (QMS) in oil companies is being developed primarily through field studies, either directly in particular contexts or in the context of oil industry general processes. This is in contrast to theoretical research.
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Similarly, Figure 5 illustrates the contribution of countries to QMS research in the oil industry, indicating the number of publications per country and the total number of citations received by these works.

With regard to the number of citations, the works conducted in the Russian Federation and Croatia achieved the highest number of citations, despite the United States and the United Kingdom having the greatest number of publications in the subject area covered by this study.

In order to assess the impact of these publications, it is noteworthy that the five publications generated in the Russian Federation collectively received a total of five citations, while the sole publication generated also reached the same number of citations.

In this context, the most prominent authors are more closely associated with the number of citations of their publications than with the number of documents, given that each author had only one publication. Consequently, an analysis was conducted based on the citations their publications had received.

By developing a map of keyword co-occurrences obtained using the Vosviewer software, it is possible to establish connections between keywords and documents, which in turn facilitate the identification of trends in research related to quality management systems (QMS) in oil companies.
Figure 5. Citations and publications numbers by country

Figure 6 shows the number of citations per author. It can be seen that the most cited document is from 2011, with a total of five citations, belongs to Dolezal (2011) and is related to a simple alternative and robust spectrometry for monitoring corrosion inhibitor residues in oilfield brine, which can be directly applied for routine monitoring purposes within QMS conditions, becoming an accredited methodology.

Figure 6. Number of citations per author

Figure 7 shows the network that interweaves the relationships between the keywords found in the publications, and the size of the nodes is related to the frequencies of the words. Each color indicates the grouping of words reached. Six groups of clusters can be seen.
The co-occurrence map delineates the interconnections established by the program. These identifications were incorporated by color, with red indicating the relationships between the quality of acquisitions and supplies and the use of machinery and products that prevent operational impact during their use throughout the process. This can be validated by reviewing the relevant certifications and standards, as well as the results of sampling audits.

The connections identified with the color green were focused on decision-making by the administrative management in collaboration with the quality and environment department. This promoted the exploration of alternatives that could mitigate or eliminate environmental risk during the preparation, execution, and completion of base-field operations. This was done in accordance with prior selective analysis of the equipment, in compliance with the regulations and laws in force in the countries.

In this context, the color blue was associated with cost analysis, critical points throughout the process, and an adequate pre-inspection of the operating equipment and the operation to be carried out. It should be noted that offshore companies require a greater investment in resources, a contingency plan for equipment and personnel on-site, and an evaluation of the risk associated with each activity, from planning to execution.

Similarly, the color yellow was associated with the verification of certifications and accreditations within the quality domain. This entailed an examination of the product, service, personnel, skills, processes, and work area, ensuring the provision of adequate and timely assurance against any operational intervention.

The purple cluster involved the analysis of offshore oil and gas production projects, including the operational aspects of production and distribution through surface facilities until the respective gas and oil pipelines. This process necessitated a rigorous security analysis by the engineering department, given the significant risks involved throughout the journey.

In accordance with the aforementioned rationale, the light blue cluster was constituted through the examination of the permissible limits of contaminants in the air. This analysis must be conducted prior to the initiation of any activity, with the objective of eliminating or mitigating the impact generated by each process. Conversely, one potential avenue for these processes is the implementation of a schedule or maintenance program, which compares the reduction of contaminant levels. This is closely aligned with the scheduled shutdowns of oil industry plants, creating avenues for improvement in the sustainable development of the industry.
The evolution of the Quality Management System (QMS) in the oil industry over time can be described in four distinct periods, as illustrated in Figure 8. From 2010 to 2011, the focus was on the integration of QMS, initially in the control of quality and risk within the oil industry, from the acquisition of equipment to the planning and execution of services. This was reflected in the management and analysis of ongoing projects, with the objective of maintaining the accreditation and competence standards of each department.

Subsequently, during the period spanning 2012 to 2014, publications on the topic focused on potential avenues for enhancement, the integration of management systems, and adherence to the requisite quality standards and competencies for each activity. Furthermore, they encompass environmental management in accordance with the legislation and regulations prevailing in each geographical area. This enables the implementation of a comprehensive decision-making system for the provision of services within the oil industry.

Subsequently, during the period spanning 2014 to 2017, a discernible shift emerges at the investigative level, encompassing all processes associated with oil well operations. This shift commences with a detailed examination of contractual agreements and the purchasing chain, with the objective of achieving sustainable development. In this pursuit, due consideration is given to the integrity of personnel, the environmental impact, and the quality of the product or service.

Furthermore, proposals are put forth to enhance air quality, including the closure of storage and refining facilities. In contrast with the overarching approach of previous investigations, this period focuses on the specific, delineating each administrative, operational, and design domain.

Subsequently, from 2017 to March 2021, a cost-benefit analysis was incorporated to guarantee quality in each process, thereby preventing potential failures or deficiencies in maintenance and inspection of the equipment utilized in production operations. The combination of these alternatives enabled a reduction in costs and a reduction in the criticality and energy impact.

CONCLUSION

The bibliometric analysis of quality management in the oil sector revealed that the methodology effectively achieved the stated objective of mapping the evolution of scientific research in the field from 2000 to 2020.
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The analysis encompassed a comprehensive range of scientific production, delineated according to various parameters such as year of publication, authorship, country of origin, language, citations, and keywords. This approach facilitated the identification of emerging trends and the formation of elite research groups on the subject.

The concept of quality management in the context of oil companies has undergone a significant evolution over time. Initially, it was primarily applied to technical or administrative processes. However, it has since expanded to encompass the entire supply and production chain, while maintaining strict compliance with relevant requirements, regulations, and current laws.

With regard to the production, service, or control lines, these have been the focus of greater attention within the oil industry with a view to developing quality management systems. The operational area of offshore and onshore companies has been particularly prominent, involving maintenance and process control in the construction of wells and surface production facilities. Furthermore, the refining phases and their environmental impact must be considered.

It was identified that the marketing and transportation phase also requires attention, as it can potentially lead to non-compliance with legal and regulatory requirements, as well as environmental concerns. Furthermore, another area meriting future research in the oil industry is the exploratory phase, during which a tectonic structural analysis may identify potential intervention sites. This necessitates the implementation of rigorous operational and administrative processes, which must be managed in accordance with established quality standards and projected to yield a productive reserve.

REFERENCES


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