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REVIEW ARTICLE

Mapping the Evolution of Risk-Based Maintenance Research: A Bibliometric Perspective

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ABSTRACT

Background: Risk-based maintenance (RBM) establishes a framework for optimizing maintenance strategies and decision-making processes. This review study presents a bibliometric analysis of peer-reviewed research in risk-based maintenance literature over recent decades. The main objective is to identify the most relevant research and the newest trends in the field, according to the information found in databases.

Methods: This study uses bibliometric methods to examine 486 publications in the Web of Science (WoS) and Scopus databases up to 21 July 2024. With the help of VOSviewer software, bibliographic connections between these publications are visualized.

Results: The analysis reveals a significant increase in publications on this topic in the past decade, with China, the United States, the United Kingdom, Japan, and Germany being the leading contributors. A large portion of the relevant documents comes from articles in the Journal of Loss Prevention in the Process Industries, with conferences being the most popular medium for sharing industry knowledge. Furthermore, the co-citation network of references reveals seven clusters: Risk Assessment, Risk-Based Maintenance, Decision Making, Inspection, Reliability and Failure Analysis, Maintenance Strategies, and Predictive Maintenance. Each cluster emphasizes strategic planning and the role of risk management in optimizing maintenance processes. Four visual outputs generated by VOSviewer—network map, overlay map, density map, and co-citation network—illustrate the relationships between scholarly articles and the interconnectedness of influential works.

Conclusion: These visualizations highlight the multifaceted nature of RBM research and provide a framework for future investigations aimed at enhancing maintenance strategies across various industries. This analysis serves as a foundational resource for researchers and practitioners seeking to navigate the landscape of RBM, guiding future research directions and practical applications.

KEYWORDS: *Risk-Based Maintenance, Safety, Reliability, Bibliometric analysis, VOS viewer*

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INTRODUCTION

Risk-Based Maintenance (RBM) is a systematic approach that improves maintenance activities by concentrating on the possible hazards associated with equipment failures. This method involves assessing both the likelihood and consequences of malfunctions, enabling more effective prioritization of maintenance tasks [1]. RBM is utilized for optimizing maintenance planning and decision-making. By employing appropriate techniques and conducting thorough investigations during risk analysis, RBM empowers stakeholders to make informed choices that minimize both the probability and consequences of equipment failure. This data-driven approach relies on rigorous analysis of structured and detailed results [2].

RBM boasts a rich history within academic literature, with studies dating back over three decades. Pioneering work includes Chen and Toyoda's (1989) proposal for an incremental risk-based approach to maintenance scheduling. The American Society of Mechanical Engineers (ASME) further propelled the field by initiating the development of Risk-Based Inspection (RBI) and associated maintenance guidelines in 1991. Khan and Haddara (2003) introduced a three-component methodology for RBM, encompassing risk estimation, evaluation, and maintenance planning [3–5].

Properly planned maintenance and inspection routines are essential for preventing equipment failures, maximizing uptime, and minimizing operational costs [6]. Kaewunruen et al. demonstrate that rail fastener failures pose a significant risk to rail safety. Existing maintenance practices are insufficient to address this issue. This research proposes a risk-based maintenance framework to enhance safety. The framework integrates standards, guidelines, and reliability tools. A case study on embedded anchors illustrates the framework's effectiveness. Accurate and ongoing risk assessment is crucial for effective maintenance [7]. Yazdi et al. created a new method to improve safety in offshore facilities by optimizing maintenance spending. They used a combination of fuzzy logic, risk assessment, and expert knowledge to make better decisions about maintenance. Testing their method on a separator system showed that it can accurately predict risks and improve overall safety [8]. A review by Tusar and Sarker analyzed 190 research articles on offshore wind farm maintenance. It found that while various maintenance strategies have been proposed, a universal solution remains elusive due to factors such as energy costs, reliability requirements, weather conditions, and workforce availability.

Some risk- and reliability-based models have shown potential to reduce annual maintenance costs by up to 23%, while opportunistic maintenance strategies can decrease production losses and transportation costs by 32%. The paper emphasizes the need to compare and contrast different models to identify optimal maintenance strategies for specific conditions. By providing insights into existing research, this review aims to guide maintenance managers in making informed decisions [9]. Iqbal et al. conducted a comprehensive review of maintenance strategies for oil and gas (O&G) pipelines. The study examined the evolution of maintenance policies from corrective to preventive and, more recently, predictive and RBM approaches. While RBM has gained traction due to improved inspection technologies and environmental regulations, challenges remain in addressing uncertainties, incorporating environmental factors into risk assessments, and balancing cost reduction with safety and environmental protection [10].

This paper employs bibliometric analysis to investigate the field of RBM. The vast amount of scientific literature can be overwhelming, hindering researchers and practitioners from obtaining a clear and organized grasp of pertinent information within their chosen discipline or topic [11]. In recent years, bibliometrics, the study of scholarly publication patterns, has become a topic of growing interest for academics [12]. Bibliometric analysis serves as a powerful tool for gaining a macroscopic perspective on vast collections of scholarly literature. Through the application of quantitative methods to publication history data, it enables

researchers to map the characteristics and trajectory of scientific output within a specific field [13]. While bibliometric data offers valuable insights into scholarly research, its interpretation requires caution. The inherent complexity of the research landscape can render such data ambiguous on its own, owing to the diversity of publication formats and the sheer volume of records (often ranging from hundreds to thousands). These characteristics reflect the multifaceted nature of research activity, encompassing both production (publications) and consumption (citations) [14]. Furthermore, bibliometric analysis goes beyond providing insights; it can significantly influence science policy and resource allocation decisions [12].

Accordingly, despite advancements, significant gaps remain in the application of RBM frameworks across diverse industries, particularly in addressing the unique challenges posed by environmental factors and uncertainties in risk assessments. As industrial systems grow in complexity and maintenance becomes increasingly critical for operational continuity, understanding the progress of research in RBM has become more important than ever. This research aims to fill this gap by systematically mapping the evolution of RBM research through a bibliometric lens, thereby providing a comprehensive overview of the field's development. The primary purpose of this study is to identify prevailing trends, challenges, and opportunities within the RBM literature, ultimately offering valuable insights for researchers and practitioners seeking to enhance their maintenance strategies in an increasingly complex operational landscape.

MATERIALS AND METHODS

This research uses data retrieved from the Web of Science (WoS) and Scopus databases on 21 July 2024 to conduct the bibliometric analysis. Considering the interdisciplinary nature of this research and the established precedent of bibliometric studies using WoS, this investigation leverages citation data from WoS, the preeminent science citation index within the ISI Web of Knowledge [15]. While WoS is recognized for its high-quality and comprehensive data collection [16], it has limitations in indexing certain conferences. To address this gap and increase the document pool for analysis, the Scopus database was also utilized. Therefore, the bibliometric data collection was conducted in this review.

The term "risk-based maintenance" was used as the search topic. This meant that the term "risk-based maintenance" needed to be identified in the title, abstract, and keywords of the publications. Quotation marks were included in the search term. Our search identified 314 documents from WoS and 434 documents from Scopus. The higher number of documents retrieved from Scopus can be attributed to two key factors. Firstly, Scopus indexes a wider range of conferences compared to WoS. Secondly, Scopus uses a broader categorization system for certain disciplines, such as engineering. For instance, Scopus groups a large number of documents under a single "Engineering" category, whereas WoS subdivides engineering into more specific categories like "Engineering Mechanical" and "Engineering Chemical." This difference in categorization explains the disparity in document count between the two databases.

The bibliographic data formats differed between WoS and Scopus: WoS provided data in tab-delimited format, while Scopus used comma-separated values (CSV) files. Subsequently, all CSV files (from both databases) were merged into a single, chronologically ordered file. While EndNote (v.8) was initially used for duplicate removal, its limitations in identifying entries with slight variations across databases were acknowledged. Therefore, a manual review process was conducted to eliminate irrelevant entries and remaining duplicates. These actions resulted in 486 documents specifically related to RBM.

The relevant details of interest were publication year, author information (including affiliation), title, abstract, source journal, and subject categories. References were extracted and exported to an Excel spreadsheet for further examination. Microsoft Excel served as the primary tool for analyzing various

aspects of the retrieved publications. These analyses included: (1) publication output and its growth trajectory, (2) authorship patterns and collaborative trends, (3) the publication landscape of RBM research (focusing on journals), (4) the geographic and institutional distribution of research activity and collaboration, (5) citation analysis to identify influential works, (6) an examination of citing and co-citation patterns to reveal intellectual relationships, and (7) subject categorization to understand the thematic breadth of the field.

Furthermore, the VOSviewer 1.6.20 software (www.vosviewer.com), a popular tool for generating and visualizing bibliometric maps, was employed to facilitate a clear understanding of the relationships between publications within the field. Researchers use VOSviewer, created by van Eck and Waltman of Leiden University, to analyze and visualize relationships among scholarly publications, authors, journals, and even countries. VOSviewer helps identify clusters of related items through color-coding, with larger items signifying greater importance and popularity within the network [17–19].

RESULTS

This section presents a review of the key findings. It delves into the publication output over time (number of documents per year), identifies the most frequently cited articles and influential authors, and highlights the journals with the highest citation impact. Additionally, an analysis of the most productive countries in this field is presented. Furthermore, to explore the intellectual landscape of sustainable technology research, this study incorporates co-citation network analysis to examine the relationships between frequently cited references and their thematic clusters. By encompassing all available publications and countries, this investigation aims to provide a holistic understanding of the field's evolution.

The study identified 219 articles, 186 conference papers, 11 reviews, 6 book chapters, and 12 editorial materials and other categories. A total of 1,151 authors, across 219 journals and 60 countries, published 434 documents (Fig. 1a). This reflects the dominance of English in scholarly publishing, as evidenced by the high proportion (89.17%) of English-language articles. In Figure 1b, the publication-year distribution shows an increasing trend. The most cited articles from the collection are revealed in Table 1.

The results showed that the article *"A Comprehensive Fuzzy Risk-Based Maintenance Framework for Prioritization of Medical Devices"* received 96 citations and primarily focused on developing a comprehensive fuzzy risk-based maintenance

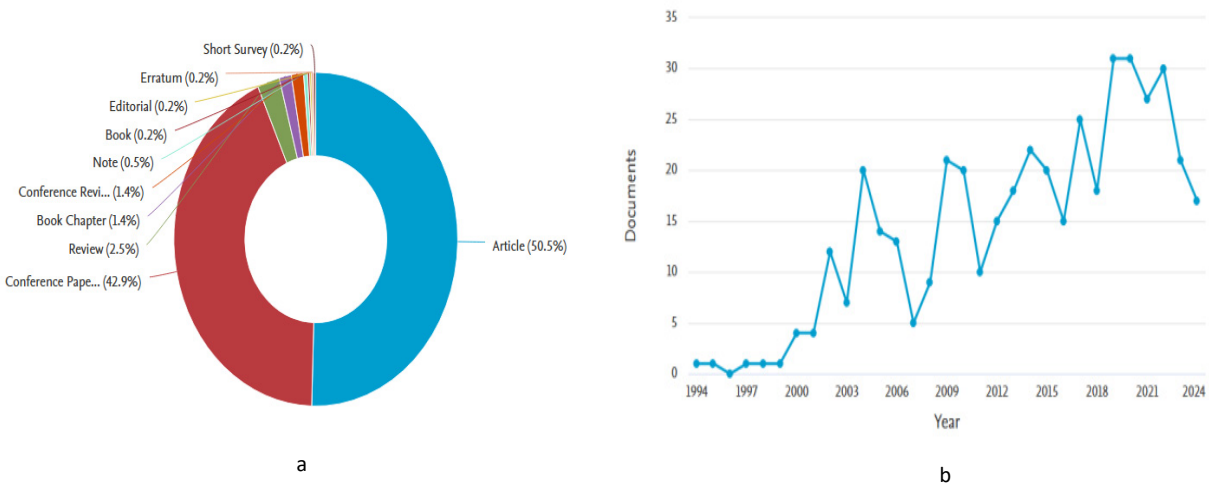

Figure 1. (a) Document type distribution and (b) publication trend in the field's evolution.

Table 1. Most cited articles on RBM

Ref	Document Title	Year	Journal Title	Total Citations
[20]	A comprehensive fuzzy risk-based maintenance framework for prioritization of medical devices	2015	Reliability Engineering and System Safety	96
[21]	Risk-based maintenance strategy selection for wind turbine composite blades	2017	Energy Reports	87
[22]	Digital twin aided vulnerability assessment and risk-based maintenance planning of bridge infrastructures exposed to extreme conditions	2021	Sustainability (Switzerland)	72
[23]	Developing a risk-based maintenance model for a Natural Gas Regulating and Metering Station using Bayesian Network	2019	Journal of Loss Prevention in the Process Industries	67
[24]	Risk-Based Maintenance Scheduling with application to naval vessels and ships	2018	Ocean Engineering	64
[25]	Optimal life-cycle resilience enhancement of aging power distribution systems: A MINLP-Based preventive maintenance planning	2020	IEEE Access	62
[26]	Risk-based pipeline integrity management: A road map for the resilient pipelines	2021	Journal of Pipeline Science and Engineering	62
[8]	Fuzzy dynamic risk-based maintenance investment optimization for offshore process facilities	2019	Journal of Loss Prevention in the Process Industries	62
[27]	Criticality analysis of petrochemical assets using risk based maintenance and the fuzzy inference system	2019	Process Safety and Environmental Protection	57
[10]	Inspection and maintenance of oil & gas pipelines: a review of policies	2017	Structure and Infrastructure Engineering	55

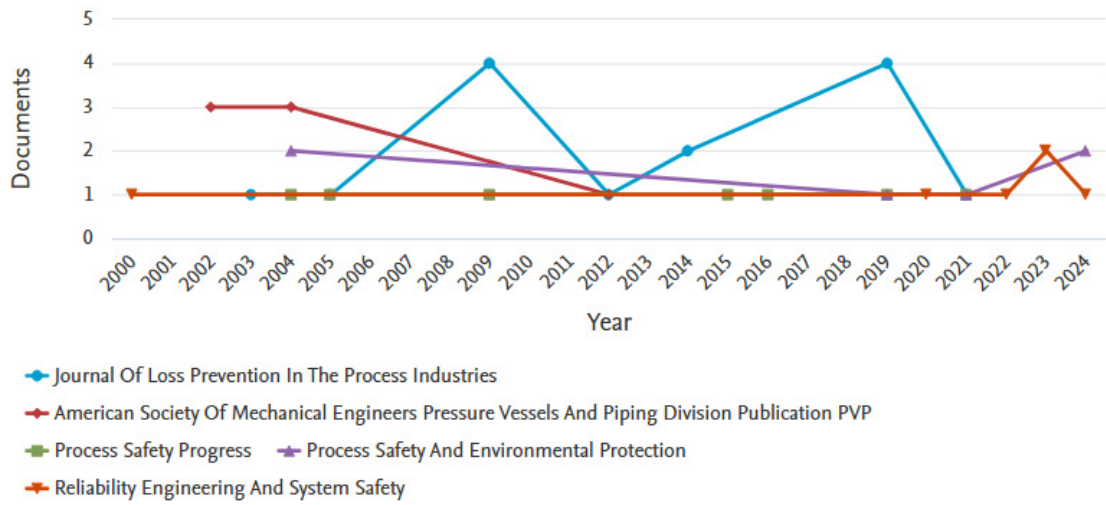

Figure 2. Most active journals publishing on RBM.

framework for prioritizing medical devices. It aimed to select the best maintenance strategy based on various risk assessment factors and criteria, ensuring the reliability and safety of medical equipment in healthcare settings, as well as exploring future directions from a technical perspective [20].

Figure 2 presents information on the most active journals publishing RBM research. It provides summary statistics for the five main sources of publications, selected based on the number of documents published. *Journal of Loss Prevention in the Process Industries* stands out among other sources with a dramatic increase. There has also been a rising trend in the number of publications in the *American Society of Mechanical Engineers Pressure Vessels and Piping Division Publication (PVP)* and *Process Safety Progress*, whereas the quantity has declined in sources such as *Process Safety and Environmental Protection* and *Reliability Engineering and System Safety*.

Figure 3 depicts the bibliographic coupling among countries. To refine the analysis, only countries with at least five documents were

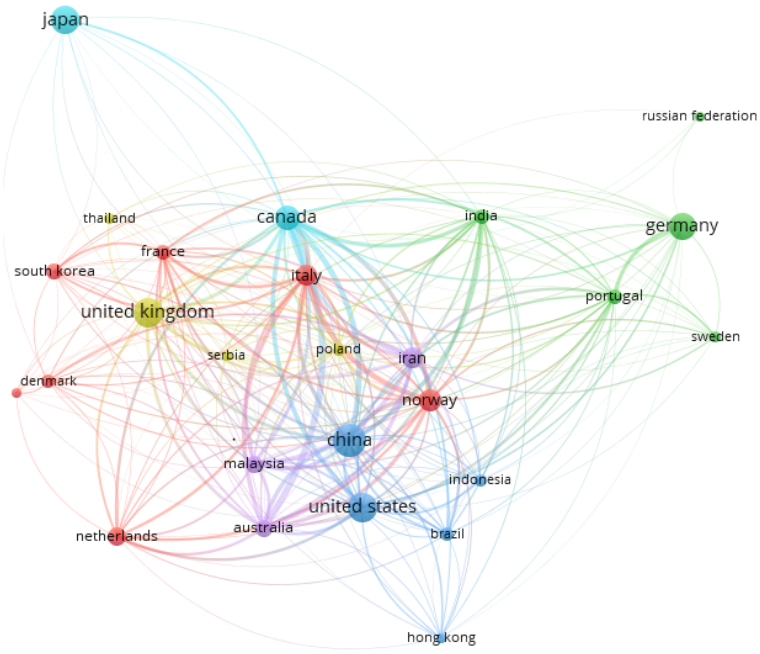

Figure 3. Countries Analysis in RBM publication areas

included. This process yielded 69 countries, which were subsequently clustered into six groups. As of 21 July 2024, China had the highest number of published articles, followed by the United Kingdom, the USA, Japan, and Germany.

Two analytical approaches were employed: co-occurrence mapping, which examines keyword relationships, and co-authorship mapping, which explores connections between authors and countries. VOSviewer software was used to process, visualize, and cluster the retrieved data. For co-occurrence mapping, all keywords were included using the full counting method. To enhance accuracy, analysis parameters were refined: a minimum keyword frequency of seven was set, and the VOSviewer thesaurus was employed to standardize author names, synonyms, and abbreviations [28]. Data cleaning was conducted using the thesaurus file, resulting in the selection of 121 keywords from an initial pool of 3214.

Cluster analysis identified three primary groups from seven clusters. Figure 4 visually represents the network of scientific papers. The word cloud indicates term frequency and interconnections. Circles symbolize terms, with size correlating to publication count. Color-coded clusters group related terms, while curved lines represent term co-occurrence, with thickness signifying relationship strength. These clusters illustrate the connections between different research topics.

Four of the seven clusters red, green, blue, and yellow are more extensive than the others. The red cluster consists of topics related to risk analysis and failure assessment in maintenance contexts. Key terms such as “probability of failure,” “structural reliability,” and “corrosion” highlight the importance of understanding the likelihood of equipment failures and the factors that contribute to them. This cluster emphasizes the need for thorough inspections and damage detection methods to mitigate risks. By analyzing these aspects, organizations can enhance their maintenance strategies, ensuring greater reliability and safety in their operations.

Cluster 2, depicted in green, centers around RBM strategies and decision-making processes. Key themes include “risk-based inspection,” “maintenance strategy,” and

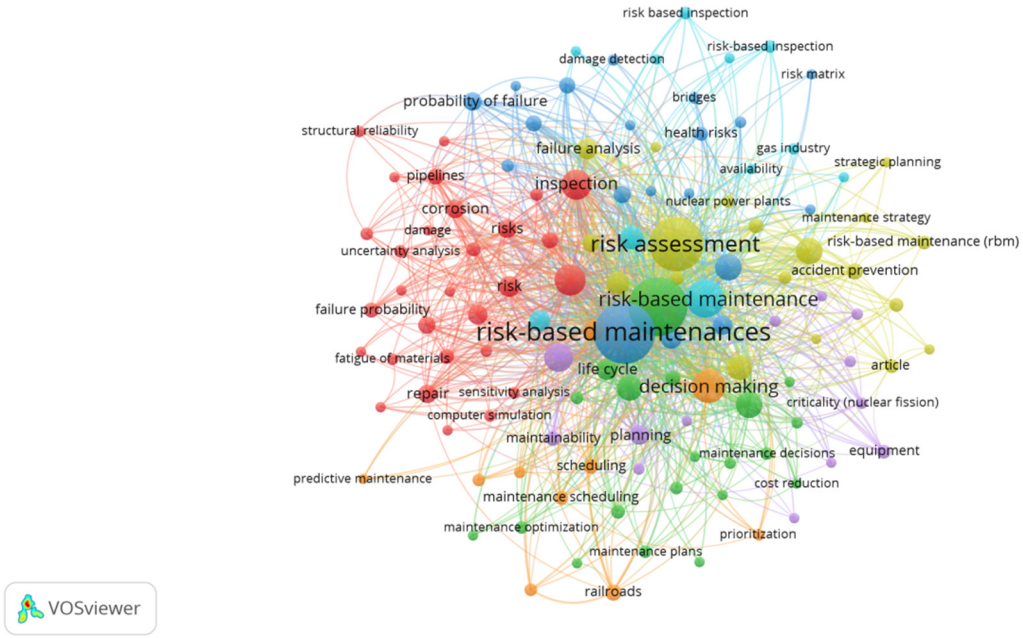

Figure 4. Network visualization.

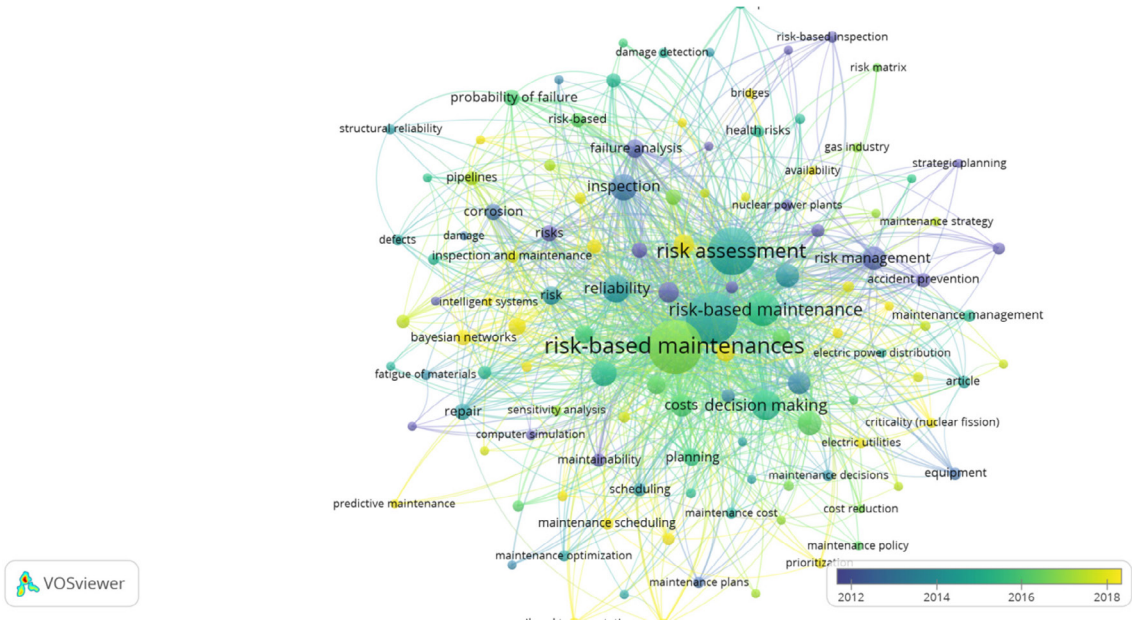

Figure 5. Overlay visualization.

"accident prevention," highlighting the importance of proactive approaches to maintenance that prioritize actions based on risk assessments. This cluster underscores the significance of strategic planning and the integration of risk management principles into maintenance activities. By focusing on these elements, organizations can optimize their maintenance efforts, improve safety outcomes, and enhance overall operational efficiency.

The blue cluster emphasizes the strategic alignment of maintenance practices with broader organizational goals. Terms like "availability," "strategic planning," and "health risks" underscore the importance of ensuring assets support operational objectives while mitigating potential harm. This cluster

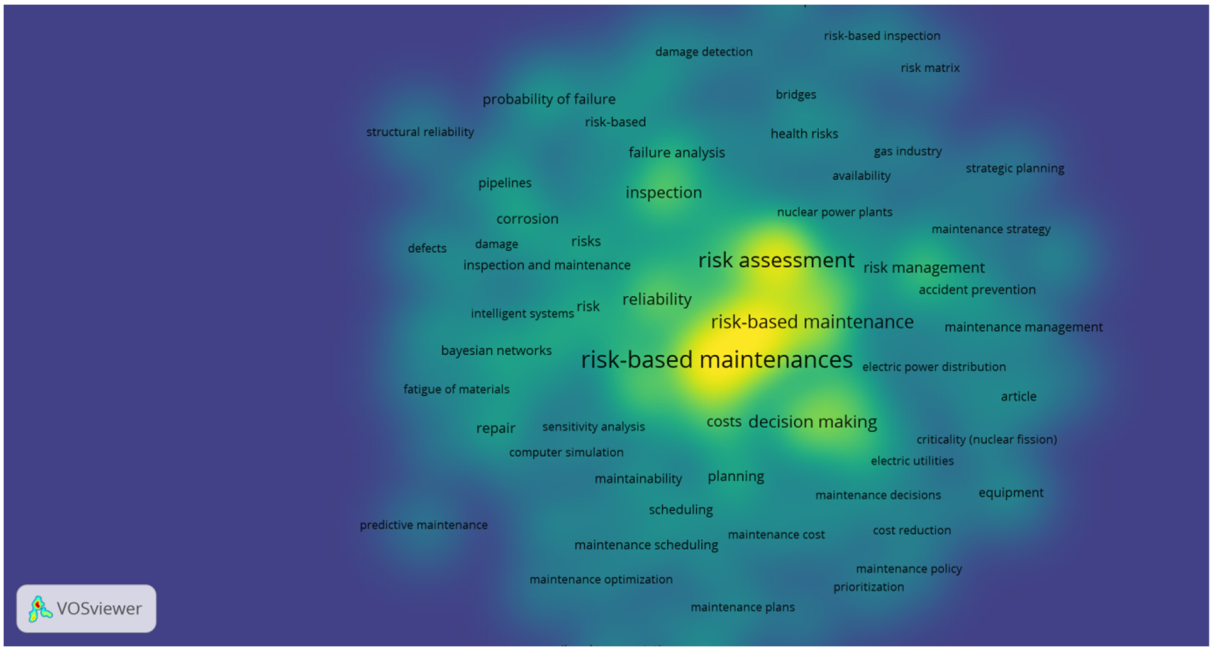

Figure 6. Density Visualization

highlights the need to integrate maintenance decisions with overall business strategy to optimize asset performance and minimize disruptions.

The yellow cluster emphasizes the economic dimensions of maintenance and risk management. Terms such as "cost reduction," "economic analysis," and "life cycle cost" highlight the financial implications of maintenance decisions. By carefully balancing maintenance expenditures with performance outcomes, organizations can optimize resource allocation and maximize the return on maintenance investments. This cluster underscores the need for a cost-effective approach to risk management.

VOSviewer generated three distinct visualizations: a network map, an overlay map, and a density map, presented in Figures 4, 5, and 6, respectively.

Figure 5 illustrates the collaborative relationships among countries based on their publication records. To refine the analysis, specific parameters were established. The figure represents the co-occurrence of keywords related to RBM and assessment. Core terms like "RBM" and "risk assessment" are central to the analysis. Surrounding keywords such as "probability of failure" and "failure analysis" highlight key research areas. The intensity of color signifies the strength of keyword relationships, revealing the interconnectedness of concepts within the field.

Only countries with at least five documents were included in the analysis shown in Figure 6. This figure was also generated by VOSviewer and focuses on keywords related to RBM and assessment. The central keywords, particularly "RBM" and "risk assessment," are highlighted in yellow, indicating their prominence in the analyzed literature. Surrounding concepts such as "probability of failure," "failure analysis," and "inspection" suggest key areas of focus in risk management practices. The varying colors represent the strength of associations between different keywords, with warmer colors indicating stronger connections. This visualization effectively illustrates the interconnectedness of various topics within the field, emphasizing the importance of risk management in maintenance strategies across industries such as energy, infrastructure, and engineering.

DISCUSSION

The bibliographic coupling analysis further

emphasizes the collaborative nature of RBM research, with six distinct clusters of countries working together. The co-occurrence and co-citation network analyses identified seven key clusters within the RBM research field. These clusters represent the interconnected nature of various research topics, including risk assessment, maintenance strategies, and predictive maintenance.

The red-designated cluster encompasses research on risk analysis and failure assessment within maintenance operations. Key concepts such as "probability of failure," "structural reliability," and "corrosion" underscore the significance of understanding the potential for equipment breakdown and its contributing factors. Structural reliability analysis (SRA) is essential both for refining safety margins in structures and for enabling a probabilistic approach to their design and operation. SRA can be employed to ensure safe and reliable structural performance throughout a system's intended lifespan. Additionally, it serves as a valuable tool for optimizing maintenance schedules to prevent failures, thereby reducing overall risk and cost [29].

Reliability assessment also offers a method for estimating the capacity of engineered structures to withstand hazardous events across their operational life cycle [30]. The study titled *"Failure Probability Assessment for Pipelines under the Corrosion Effect"* defines the reliability index and probability-of-failure evolution for pipelines subjected to corrosion. By coupling mechanical and reliability models, the researchers quantified the evolution of failure probability over time. The model incorporated both uniform and localized corrosion, with material properties determined through hardness and tensile tests [31]. Dundulis et al. developed a comprehensive framework for predicting pipeline failure probability. Their approach integrates deterministic and probabilistic structural analysis, accounting for factors such as loads, material properties, and defects. To improve accuracy, they incorporated corrosion rates, defect data, and historical failure information into the model using Bayesian methods [32].

Clusters depicted in green include "risk-based inspection," "maintenance strategy," and "accident prevention," highlighting the importance of proactive approaches to maintenance that prioritize actions based on risk assessments. Risk-based inspection (RBI) and maintenance strategies have become increasingly interconnected in recent years. There is a growing trend toward using risk assessment to select the most effective maintenance approach. RBI is a systematic method used primarily in the oil and gas industry to prioritize and plan inspections. It involves evaluating the likelihood and potential consequences of equipment failure to develop an optimized inspection strategy [33].

Guang Zou et al. proposed a risk-based approach to optimize the design, inspection, and maintenance of fatigue-sensitive components. Their method integrates structural design and operational maintenance decisions to maximize fatigue reliability and minimize costs. By considering uncertainties and failure consequences, they determine the optimal structural design and maintenance strategies simultaneously. This holistic approach leads to improved component life cycle performance compared to traditional methods that address design and maintenance separately [34].

Tubis et al. introduced a novel approach to mining machinery maintenance management, incorporating RBM principles with a strong emphasis on safety. Their methodology comprises a five-step process, beginning with hazard analysis and progressing through risk evaluation to ultimately yield recommendations for maintenance, safety, and resource allocation. This approach aims to optimize maintenance strategies by prioritizing safety and efficient resource utilization within the mining sector [35].

The multidisciplinary nature of RBM underscores the need for comprehensive frameworks that integrate risk assessment, decision-making, and economic considerations. Risk assessment is crucial for informing maintenance decisions it helps

identify, prioritize, and develop effective maintenance plans. However, the success of these plans depends on how well the risk assessment accounts for the interconnectedness of asset failures [36].

The blue cluster emphasizes the strategic alignment of maintenance practices with broader organizational objectives, focusing on asset availability, strategic planning, and health risks. This cluster underscores the need to integrate maintenance decisions with overall business strategy to optimize asset performance and minimize disruptions. Conversely, the yellow cluster highlights the economic dimensions of maintenance and risk management, emphasizing cost reduction, economic analysis, and life cycle cost. By balancing maintenance expenditures with performance outcomes, organizations can optimize resource allocation and maximize the return on maintenance investments. Together, these clusters demonstrate the need for a comprehensive approach to maintenance that considers both strategic and economic factors to effectively manage risk and optimize asset lifecycle costs.

Fernández and colleagues developed a practical approach for adjusting maintenance plans on the fly. This method relies on continuously assessing risk based on real-time data from monitoring and maintenance activities within a condition-based maintenance system. The authors aligned their risk assessment framework with ISO 31000 to ensure compatibility with other risk management methods [37]. As industrial systems become increasingly intricate, stakeholders are seeking to maximize the efficiency and lifespan of these systems. This has placed particular emphasis on optimizing maintenance operations. Louhichi and colleagues developed a novel approach to maintenance planning that considers both the financial implications of maintenance activities and the potential risks associated with system failures. Unlike previous methods, their model incorporates a comprehensive set of costs including financial, environmental, and human risks into a single optimization function [38].

Remaining useful life (RUL) prediction is an advanced technique for system maintenance scheduling. Most existing RUL prediction methods focus solely on estimation accuracy, often overlooking the adverse impact of overestimated RUL on maintenance scheduling [39].

LIMITATION

The study's findings are subject to limitations. Relying solely on WoS and Scopus may exclude relevant research from regional or less accessible publications. Additionally, using citation counts to measure research impact can be misleading, as it may overlook valuable but under-cited studies. Future research should broaden its database scope to include non-English publications and incorporate qualitative assessments of research impact. This study serves as a foundation for future explorations in RBM, encouraging further research into its methodologies and applications.

CONCLUSION

A bibliometric analysis of RBM literature offers valuable insights into the field's trajectory and contemporary trends. The substantial growth in RBM publications over the past decade underscores its increasing importance in optimizing maintenance practices across diverse sectors. Key research hubs, including China, the United States, and the United Kingdom, highlight the global focus on improving maintenance through risk assessment. The analysis identified seven distinct research clusters, including risk assessment, decision-making, and predictive maintenance, emphasizing the multifaceted nature of RBM.

Employing VOSviewer, the study visualized intricate connections between publications, authors, and research themes. *The Journal of Loss Prevention in the Process Industries* emerged as a leading platform for RBM research, facilitating knowledge dissemination and fostering discussions on effective maintenance strategies. Many studies integrate advanced methodologies, such as fuzzy logic and Bayesian networks, into RBM frameworks to enhance decision-making and

prioritize maintenance actions based on risk assessments.

REFERENCES

1. Arunraj N, Maiti J. Risk-based maintenance—techniques and applications. J Hazard Mater. 2007;142(3):653–61.
2. Leoni L, De Carlo F, Paltrinieri N, Sgarbossa F, BahooToroody A. On risk-based maintenance: a comprehensive review of three approaches to track the impact of consequence modelling for predicting maintenance actions. J Loss Prev Process Ind. 2021;72:104555.
3. Grimstad J, Ruppert T, Abonyi J, Morozov A. Preventive risk-based maintenance scheduling using discrete-time Markov chain models. 2023.
4. Chen L, Toyoda J, editors. Maintenance scheduling based on two level hierarchical structure to equalize incremental risk. In: Proc Power Ind Comput Appl Conf. IEEE; 1989.
5. Khan FI, Haddara MM. Risk-based maintenance (RBM): a quantitative approach for maintenance/inspection scheduling and planning. J Loss Prev Process Ind. 2003;16(6):561–73.
6. Leoni L, De Carlo F, Sgarbossa F, Paltrinieri N. Comparison of risk-based maintenance approaches applied to a natural gas regulating and metering station. 2020.
7. Kaewunruen S, Osman MH, Cheng EWH. Risk-based maintenance planning for rail fastening systems. ASCE-ASME J Risk Uncertain Eng Syst Part A Civ Eng. 2019;5(3):04019007.
8. Yazdi M, Nedjati A, Abbassi R. Fuzzy dynamic risk-based maintenance investment optimization for offshore process facilities. J Loss Prev Process Ind. 2019;57:194–207.
9. Tusar MIH, Sarker BR. Maintenance cost minimization models for offshore wind farms: a systematic and critical review. Int J Energy Res. 2022;46(4):3739–65.
10. Iqbal H, Tesfamariam S, Haider H, Sadiq R. Inspection and maintenance of oil & gas pipelines: a review of policies. Struct Infrastruct Eng. 2017;13(6):794–815.
11. Alsharif AH, Salleh N, Baharun R. Bibliometric analysis. J Theor Appl Inf Technol. 2020;98(15):2948–62.
12. Ellegaard O. The application of bibliometric analysis: disciplinary and user aspects. Scientometrics. 2018;116(1):181–202.
13. Mukherjee D, Lim WM, Kumar S, Donthu N. Guidelines for advancing theory and practice through bibliometric research. J Bus Res. 2022;148:101–15.
14. Lim WM, Kumar S. Guidelines for interpreting the results of bibliometric analysis: a sensemaking approach. Glob Bus Organ Excell. 2024;43(2):17–26.
15. Fetscherin M, Usunier JC. Corporate branding: an interdisciplinary literature review. Eur J Mark. 2012;46(5):733–53.
16. Paganin L, Borsato M. A critical review of design for reliability—a bibliometric analysis and identification of research opportunities. Procedia Manuf. 2017;11:1421–8.
17. Li J, Mao Y, Ouyang J, Zheng S. A review of urban microclimate research based on CiteSpace and VOSviewer analysis. Int J Environ Res Public Health. 2022;19(8):4741.
18. Llanos-Herrera GR, Merigo JM. Overview of brand personality research with bibliometric indicators. Kybernetes. 2019;48(3):546–69.
19. Van Eck NJ, Waltman L. Software survey: VOSviewer, a computer program for bibliometric mapping. Scientometrics. 2010;84(2):523–38.
20. Jamshidi A, Rahimi SA, Ait-Kadi D, Ruiz A. A comprehensive fuzzy risk-based maintenance framework for prioritization of medical devices. *Appl Soft Comput*. 2015;32:322–34.
21. Arzaghi E, Abaei MM, Abbassi R, Garaniya V, Chin C, Khan F. Risk-based maintenance planning of subsea pipelines through fatigue crack growth monitoring. Eng Fail Anal. 2017;79:928–39.
22. Kaewunruen S, Sresakoolchai J, Ma W, Phil-Ebosie O. Digital twin aided vulnerability assessment and risk-based maintenance planning of bridge infrastructures exposed to extreme conditions. Sustainability (Basel). 2021;13(4):2051.
23. Leoni L, BahooToroody A, De Carlo F, Paltrinieri N. Developing a risk-based maintenance model for a natural gas regulating and metering station using Bayesian network. J Loss Prev Process Ind. 2019;57:17–24.
24. Cullum J, Binns J, Lonsdale M, Abbassi R, Garaniya V. Risk-based maintenance scheduling with application to naval vessels and ships. Ocean Eng. 2018;148:476–85.
25. Dehghani NL, Darestani YM, Shafieezadeh A. Optimal life-cycle resilience enhancement of aging power distribution systems: a MINLP-based preventive maintenance planning. IEEE Access. 2020;8:22324–34.
26. Khan F, Yarveisy R, Abbassi R. Risk-based pipeline integrity management: a road map for the resilient pipelines. J Pipeline Sci Eng. 2021;1(1):74–87.
27. Jaderi F, Ibrahim ZZ, Zahiri MR. Criticality analysis of petrochemical assets using risk-based maintenance and the fuzzy inference system. Process Saf Environ Prot. 2019;121:312–25.
28. Van Eck NJ, Waltman L. VOSviewer manual. Leiden: Univ Leiden; 2018.
29. Afshari SS, Enayatollahi F, Xu X, Liang X. Machine learning-based methods in structural reliability analysis: a review. Reliab Eng Syst Saf. 2022;219:108223.
30. Wang C, Beer M, Ayyub BM. Time-dependent reliability of aging structures: overview of assessment methods. ASCE-ASME J Risk Uncertain Eng Syst A Civ Eng. 2021;7(4):03121003.
31. Nahal M, Khelif R. Failure probability assessment for pipelines under the corrosion effect. Am J Mech Eng. 2014;2(1):15–20.
32. Dundulis G, Žutautaitė I, Janulionis R, Uščpuras E, Rimkevičius S, Eid M. Integrated failure probability estimation based on structural integrity analysis and failure data: natural gas pipeline case. Reliab Eng Syst Saf. 2016;156:195–202.
33. Tan Z, Li J, Wu Z, Zheng J, He W. An evaluation of maintenance strategy using risk-based inspection. Saf Sci. 2011;49(6):852–60.
34. Zou G, Faber MH, González A, Banisoleiman K. A holistic approach to risk-based decision on inspection and design of fatigue-sensitive structures. Eng Struct. 2020;221:110949.
35. Tubis A, Werbińska-Wojciechowska S, Sliwinski P, Zimroz R. Fuzzy risk-based maintenance strategy with safety

considerations for the mining industry. Sensors (Basel). 2022;22(2):441.
36. Chemweno P, Pintelon L, Muchiri PN, Van Horenbeek A. Risk assessment methodologies in maintenance decision making: a review of dependability modelling approaches. Reliab Eng Syst Saf. 2018;173:64–77.
37. Fernández PMG, López AJG, Márquez AC, Fernández JFG, Marcos JA. Dynamic risk assessment for CBM-based adaptation of maintenance planning. Reliab Eng Syst Saf. 2022;223:108359.
38. Louhichi R, Sallak M, Pelletan J. A cost model for predictive maintenance based on risk-assessment. In: Proc CIGI QUALITA. 2019.
39. Chen C, Lu N, Jiang B, Wang C. A risk-averse remaining useful life estimation for predictive maintenance. IEEE/CAA J Autom Sin. 2021;8(2):412–22.