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RESEARCH TREND ON EMERGENCY RESPONSE PLANNING (ERP) FOR MAJOR HAZARD INDUSTRIES

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Abstract:

Emergency Response Planning (ERP) for major hazard industries has gained critical global attention due to the increasing frequency and severity of industrial accidents, natural disasters, and complex emergencies. Despite its significance, the academic landscape on this topic remains fragmented, necessitating a comprehensive evaluation of existing research trends and intellectual structures. This study aims to bridge that gap by conducting a bibliometric analysis of 1,291 relevant publications indexed in the Scopus database. Using Scopus Analyzer for data extraction, OpenRefine for data cleaning and normalization, and VOSviewer for visualization and network mapping, we systematically explored publication trends, prolific authors, leading countries, top-cited papers, and thematic clusters. The results demonstrate a significant growth in publications from 2015 to 2024, with China and the United States (US) emerging as the most productive contributors. Key research themes include logistics and resource optimization, Unmanned Aerial Vehicle (UAV) deployment for emergency operations, multi-criteria decision-making frameworks, and the integration of artificial intelligence in response planning. Highly cited works reflect a strong interest in both technological advancements and policy-driven approaches. Furthermore, co-authorship and keyword co-occurrence networks reveal strong regional collaboration patterns and evolving research foci over time. This study highlights the interdisciplinary nature and expanding scope of ERP, emphasizing the need for greater international collaboration and integration of emerging technologies. In conclusion, this bibliometric analysis provides valuable insights into the development, current state, and future directions of research in ERP for major

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hazard industries. It also serves as a foundational reference for scholars, practitioners, and policymakers alike.

Keywords:

Disaster Management, Preparedness Strategies, Industrial Safety, Bibliometric Analysis

Introduction

Emergency Response Planning (ERP) for major hazard industries is critical to risk management and safety protocols. These industries, including chemical plants, oil refineries, and offshore drilling sites, are characterized by high-risk operations that can lead to catastrophic events such as toxic gas leaks, fires, explosions, and structural failures. In particular, the significance of ERP lies in its ability to mitigate the impacts of such incidents, protect human lives, minimize environmental damage, and ensure the continuity of operations. Effective ERP involves comprehensive strategies that encompass hazard identification, risk assessment, emergency preparedness, and response mechanisms tailored to specific industrial contexts (Hosseinnia et al., 2018; Sandres et al., 2008; Strong, 2009).

Recent developments in ERP have focused on integrating advanced technologies and methodologies to enhance the effectiveness of emergency responses. Geographic Information Systems (GIS) and risk analyses are increasingly utilized to support decision-making during critical situations. They provide georeferenced data and spatially integrated analyses vital for external emergency planning (Sandres et al., 2008). At the same time, Computational Fluid Dynamics (CFD) modeling has also emerged as a powerful tool for consequence analysis, offering high-quality visualization and monitoring capabilities that improve the accuracy of emergency response plans (Brumbaugh et al., 2014; Widagdo & Cahyono, 2020). These technological advancements enable more precise predictions of hazardous scenarios, facilitating timely and effective interventions.

Moreover, the significance of multi-plant ERP in chemical clusters has been recognized, addressing the need for coordinated strategies across multiple facilities to manage crises more efficiently (Hosseinnia et al., 2018). Training and preparedness are essential components of ERP, with tailored training programs designed to enhance the readiness of emergency response teams. In addition, the integration of human reliability analysis and decision-making frameworks helps identify and mitigate human errors during emergency drills. This ensures that personnel are well-equipped to manage real emergencies (Ahn et al., 2022; Charlton & Sinclair, 2012; Naderi et al., 2020).

Despite these advancements, challenges remain in the implementation and effectiveness of ERP. Studies have highlighted gaps in risk assessment processes and the need for continuous improvement in emergency preparedness capabilities (Perseval & Baldeo, 2022; Rashid et al., 2023). The complexity of emergency response procedures, particularly in off-site scenarios involving multiple parties and unclear responsibilities, necessitates robust auditing and drilling practices to maintain effective ERP (Su, 2014). Additionally, the unique challenges posed by natural events in Natech (natural hazards triggering technological accidents) scenarios require specialized methodologies to assess and enhance emergency response performance (Ricci et al., 2024).

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ERP for major hazard industries is a dynamic and evolving field that demands ongoing attention to technological integration, multi-facility coordination, and rigorous training and preparedness. By addressing these aspects, industries can better manage the risks associated with high-hazard operations, ensuring the safety of personnel, protection of the environment, and resilience of industrial activities in the face of potential disasters.

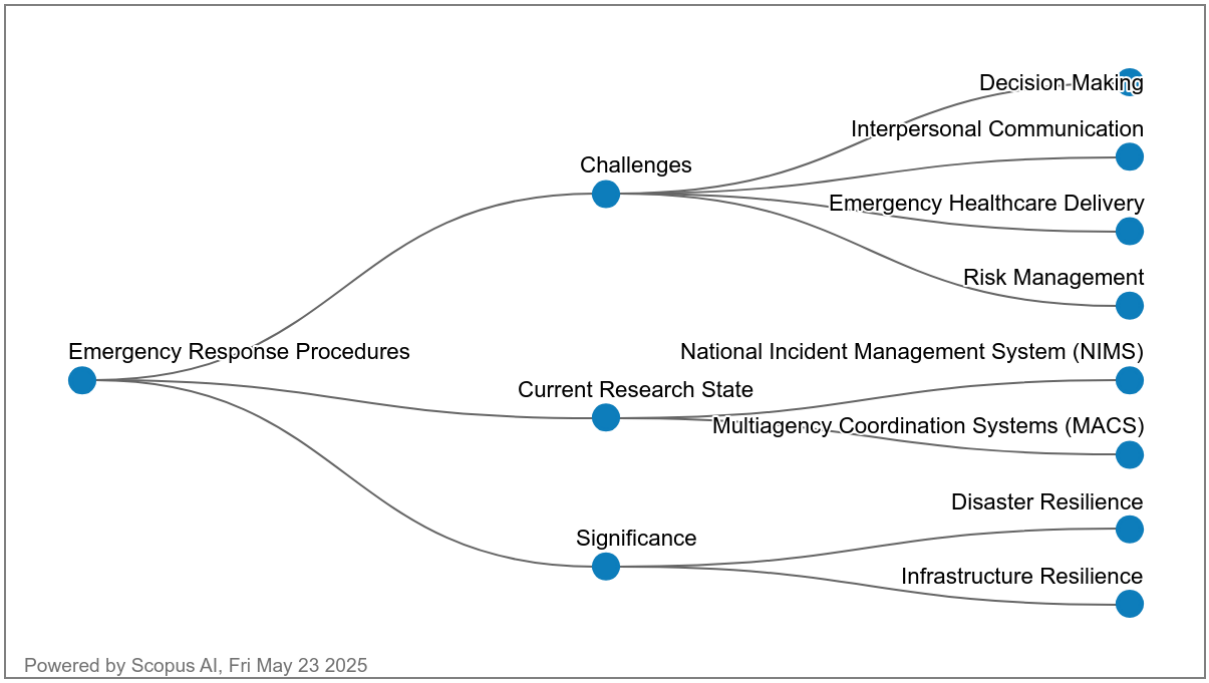

Figure 1: Overview Of Emergency Response Planning/ Procedure Research Trend

Research Questions

To systematically explore the development and current state of research in this field, the study is guided by five core Research Questions (RQs) as follows:

RQ1: What are the research trends pertaining to ERP for major hazard industries according to the year of publication?

RQ2: What are the most cited articles?

RQ3: Which are the top 10 countries based on the number of publications?

RQ4: What are the popular keywords related to the study during the last ten years?

RQ5: What is the co-authorship collaboration between countries?

Methodology

Bibliometrics involves gathering, organizing, and analyzing bibliographic data from scientific publications (Alves et al., 2021; Assyakur & Rosa, 2022; Verbeek et al., 2002). Beyond basic statistics, such as identifying publishing journals, publication years, and leading authors (Wu & Wu, 2017), bibliometrics includes more sophisticated techniques like document co-citation analysis. Conducting a successful literature review requires a careful, iterative process to select suitable keywords, search the literature, and perform an in-depth analysis. This approach helps to compile a comprehensive bibliography and achieve reliable results (Fahimnia et al., 2015). With this in mind, the study focused on high-impact publications, as they provide meaningful insights into the theoretical frameworks that shape the research field. To ensure data accuracy, Scopus served as the primary source for data collection (Al-Khoury et al., 2022; Stefano et al., 2010; Khiste & Paithankar, 2017). Additionally, to maintain quality, the study only considered

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articles published in peer-reviewed academic journals, deliberately excluding books and lecture notes (Gu et al., 2019). Using Elsevier's Scopus, known for its broad coverage, publications were collected from 2015 through 2025 for further analysis.

Data Search Strategy

This study employed a screening sequence to determine the search terms for article retrieval. This study was initiated by querying the Scopus online database. Afterwards, the query string was revised to ensure that the search terms emergency, accident, response, and preparedness should focus on emergency response and preparedness. This process yielded 4,603 results, which were further scrutinized to include only research articles related to engineering and chemical engineering. The final search string refinement included 1,291 articles, which were used for bibliometric analysis. As of May 2025, all articles from the Scopus database relating to emergency response were incorporated in the study.

Table 1: The Search String

Scopus	TITLE ((emergency OR accident) AND (response OR preparedness)) AND PUBYEAR > 2014 AND PUBYEAR < 2026 AND (LIMIT-TO (SUBJAREA, "ENGI") OR LIMIT-TO (SUBJAREA, "CENG")) AND (EXCLUDE (EXACTKEYWORD, "Earthquakes") OR EXCLUDE (EXACTKEYWORD, "COVID-19") OR EXCLUDE (EXACTKEYWORD, "Adult") OR EXCLUDE (EXACTKEYWORD, "Petri Nets") OR EXCLUDE (EXACTKEYWORD, "Integer Programming") OR EXCLUDE (EXACTKEYWORD, "Stochastic Systems") OR EXCLUDE (EXACTKEYWORD, "Robotics") OR EXCLUDE (EXACTKEYWORD, "Management") OR EXCLUDE (EXACTKEYWORD, "Data Acquisition") OR EXCLUDE (EXACTKEYWORD, "Semantics") OR EXCLUDE (EXACTKEYWORD, "Motor Transportation") OR EXCLUDE (EXACTKEYWORD, "Algorithm") OR EXCLUDE (EXACTKEYWORD, "Ships") OR EXCLUDE (EXACTKEYWORD, "Data Handling"))

Table 2: The Selection Criterion

Criterion	Inclusion	Exclusion
Language	English	Non-English
Timeline	2015 - 2025	< 2015
Subject area	Engineering and Chemical Engineering	Besides Engineering and Chemical Engineering

Data Analysis

VOSviewer is a user-friendly bibliometric software developed by Nees Jan van Eck and Ludo Waltman at Leiden University, Netherlands (Van Eck & Waltman, 2010, 2017). Widely utilized for visualizing and analyzing scientific literature, the tool specializes in creating intuitive network visualizations, clustering related items, and generating density maps. Its versatility allows for the examination of co-authorship, co-citation, and keyword co-occurrence

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networks, providing researchers with a comprehensive understanding of research landscapes. The interactive interface, coupled with continuous updates, ensures efficient and dynamic exploration of large datasets. Furthermore, VOSviewer's ability to compute metrics, customize visualizations, and its compatibility with various bibliometric data sources make it valuable for scholars seeking insights into complex research domains.

One of the standout features of VOSviewer is its capacity to transform intricate bibliometric datasets into visually interpretable maps and charts. With a focus on network visualization, the software excels in clustering related items, analyzing keyword co-occurrence patterns, and generating density maps. Researchers benefit from its user-friendly interface, enabling both novice and experienced users to explore research landscapes efficiently. In addition, VOSviewer's continuous development ensures it remains at the forefront of bibliometric analysis, offering valuable insights through metrics computation and customizable visualizations. Its adaptability to various types of bibliometric data, such as co-authorship and citation networks, positions VOSviewer as a versatile and indispensable tool for scholars seeking deeper understanding and meaningful insights within their research domains.

Datasets comprising information on the publication year, title, author name, journal, citation, and keywords in PlainText format were procured from the Scopus database, spanning the period from 2004 to December 2024. These datasets were then analyzed using VOSviewer software version 1.6.19. Through the application of VOS clustering and mapping techniques, this software facilitated the examination and generation of maps. Offering an alternative to the Multidimensional Scaling (MDS) approach, VOSviewer focuses on situating items within low-dimensional spaces, ensuring that the proximity between any two items accurately reflects their relatedness and similarity (van Eck & Waltman, 2010). In this respect, VOSviewer shares a similarity with the MDS approach (Appio et al., 2014). Diverging from MDS, which primarily engages in the computation of similarity metrics like cosine and Jaccard indices, VOS utilizes a more fitting method for normalizing co-occurrence frequencies. This includes the Association Strength (AS_{ij}), and it is calculated as (Van Eck & Waltman, 2007):

$$AS_{ij} = \frac{C_{ij}}{w_i w_j},$$

which is "proportional to the ratio between, on the one hand, the observed number of co-occurrences of i and j and, on the other hand, the expected number of co-occurrences of i and j under the assumption that co-occurrences of i and j are statistically independent" (Van Eck & Waltman, 2007).

This study employed a screening sequence to determine the search terms for article retrieval. This study was initiated by querying the Scopus database online. Afterwards, the query string was revised to ensure that the search terms emergency, accident, response, and preparedness focus on emergency response and preparedness. This process yielded 4,603 results, which were further scrutinized to include only research articles related to engineering and chemical engineering. The final search string refinement included 1,291 articles, which were used for bibliometric analysis. As of May 2025, all articles from the Scopus database relating to emergency response were incorporated in the study.

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Findings

RQ1: What Are The Research Trends Pertaining to Emergency Response Planning for Major Hazard Industries According to The Year Of Publication?

The bibliometric data from 2015 to 2025 demonstrate a generally upward trend in publications on emergency response plans for major hazard industries, as displayed in Figure 2, reflecting increasing academic and professional interest in this critical area. Notably, the number of publications surged from 101 in 2015 to a peak of 195 in 2024, marking a nearly twofold increase over the decade. This steady growth suggests a heightened global awareness of industrial risks and a parallel push for preparedness and response mechanisms. Notably, the increase could also be associated with emerging global challenges such as climate change, geopolitical instability, and pandemics. This amplifies the urgency for robust emergency planning in high-risk industrial sectors.

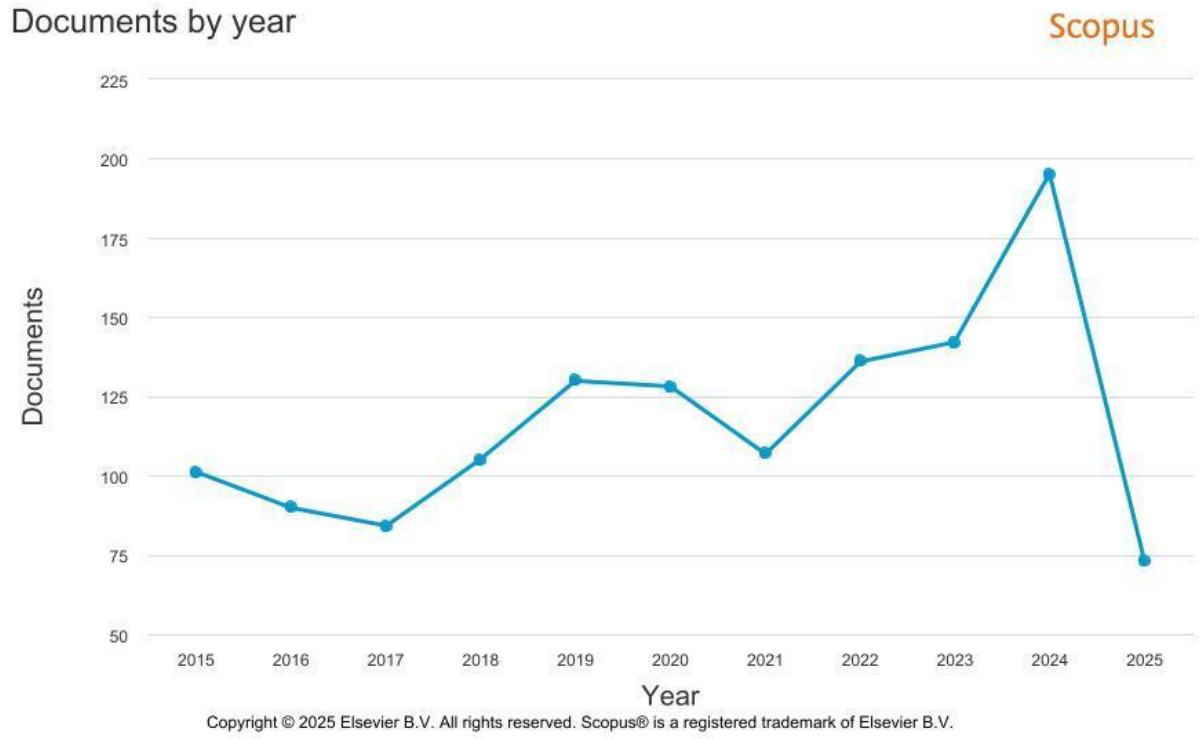

Figure 2: Trend of Publication By Year

The data reveal some fluctuations within the decade. After a decrease to 84 publications in 2017, the number rebounded and maintained a generally upward trajectory until 2024. Interestingly, 2020 to 2022 demonstrated particularly strong and consistent output (128, 107, and 136 publications, respectively). This may correlate with the COVID-19 pandemic era, during which resilience planning and emergency management drew significant attention across industries. In addition, this period may have spurred interdisciplinary research and policy-oriented studies, highlighting vulnerabilities in existing response strategies and promoting innovations in hazard preparedness.

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Table 3: Number and Percentage of Publications Based on Publication Year

Year	Number of Publications	Percentage (%)
2025	73	5.65
2024	195	15.10
2023	142	11.00
2022	136	10.53
2021	107	8.29
2020	128	9.91
2019	130	10.07
2018	105	8.13
2017	84	6.51
2016	90	6.97
2015	101	7.82

In 2025, although the year is still in progress, there is already a notable count of 73 publications, comprising 5.65% of the total dataset, as presented in Table 3. While this is lower than the previous year, it should be interpreted with caution, as data collection for 2025 may still be ongoing. If this trend continues, it might indicate a stabilization or slight decline in publication volume, possibly reflecting saturation in foundational research or a shift toward implementation and policy application rather than theoretical development. Overall, the decade's trend underscores an evolving and expanding research landscape focused on enhancing emergency response frameworks in major hazard industries.

RQ2: What Are The Most Cited Articles?

The analysis of the top ten most cited articles on ERP highlights a rich diversity of research themes and technological applications. Table 4 outlines the most cited paper by Ni et al. (2018) with 170 citations, emphasizing logistical optimization through a min-max robust model. This reflects the foundational significance of resource pre-positioning in disaster response. Similarly, G. Li et al. (2022) significantly contributed to decision-making through fuzzy cluster analysis, indicating growing interest in computational models that address the complexity of stakeholder preferences in emergency planning scenarios.

Table 4: Top 10 Most Cited Authors

Authors	Title	Year	Source title	Cited by
Ni et al.	Location and Emergency Inventory Pre-Positioning for Disaster Response Operations: Min-Max Robust Model and a Case Study of Yushu Earthquake	2018	Production and Operations Management	170
G. Li et al.	Heterogeneous Large-Scale Group Decision Making Using Fuzzy Cluster Analysis and Its Application to Emergency Response Plan Selection	2022	IEEE Transactions on Systems, Man, and Cybernetics: Systems	158

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Boccardo et al.	UAV deployment exercise for mapping purposes: Evaluation of emergency response applications	2015	Sensors (Switzerland)	147
Wan et al.	An Accurate UAV 3-D Path Planning Method for Disaster Emergency Response Based on an Improved Multiobjective Swarm Intelligence Algorithm	2023	IEEE Transactions on Cybernetics	119
Kyrkou & Theocharides	Deep-learning-based aerial image classification for emergency response applications using unmanned aerial vehicles	2019	IEEE Computer Society Conference on Computer Vision and Pattern Recognition Workshops	115
Hou et al.	Hazardous chemical leakage accidents and emergency evacuation response from 2009 to 2018 in China: A review	2021	Safety Science	113
Li & Cao	Extended TODIM method for multi-attribute risk decision-making problems in emergency response	2019	Computers and Industrial Engineering	98
Mejia et al.	Operational Transparency on Crowdfunding Platforms: Effect on Donations for Emergency Response	2019	Production and Operations Management	94
Laylavi et al.	Event-relatedness assessment of Twitter messages for emergency response	2017	Information Processing and Management	84
Zhang et al.	A truthful incentive mechanism for emergency demand response in colocation data centers	2015	Proceedings - IEEE INFOCOM	83

Technology-oriented research features prominently, particularly involving Unmanned Aerial Vehicles (UAVs). Three highly cited studies by Boccardo et al. (2015), Wan et al. (2023), and Kyrkou and Theocharides (2019) explored UAV deployment, 3D path planning, and deep learning for aerial image classification, respectively. The collective citations of these papers reflect the field's shift toward intelligent systems for real-time data collection, terrain analysis, and automated decision support. Accordingly, these works underscore how cutting-edge tools like swarm intelligence and machine learning are becoming central to enhancing the effectiveness and efficiency of emergency response operations.

Additional studies expand the thematic range beyond logistics and technology. For instance, Hou et al. (2021) conducted a national-scale review of chemical accidents in China, offering policy-relevant insights. Others, like Li and Cao (2019) and Mejia et al. (2019), addressed behavioral and financial dimensions, focusing on decision-making frameworks and transparency in emergency-related crowdfunding. Meanwhile, Laylavi et al.'s (2017) analysis of Twitter data introduced social media as a critical resource for situational awareness.

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Together, these top-cited papers illustrate a multidimensional research landscape that integrates operational models, smart technologies, and human behavior to support comprehensive emergency response strategies.

RQ3: Which Are The Top 10 Countries Based on the Number of Publications

The bibliometric analysis by country reveals that China leads in research output on emergency response plans for major hazard industries, contributing 372 publications as demonstrated in Figure 3. This dominant position reflects China's growing academic infrastructure, significant industrial base, and increasing policy emphasis on safety and disaster preparedness. With its history of large-scale industrial accidents and natural disasters, China is motivated to invest in research that enhances emergency management systems. Moreover, this leadership may also be attributed to government-driven funding programs and collaboration between academia and state agencies.

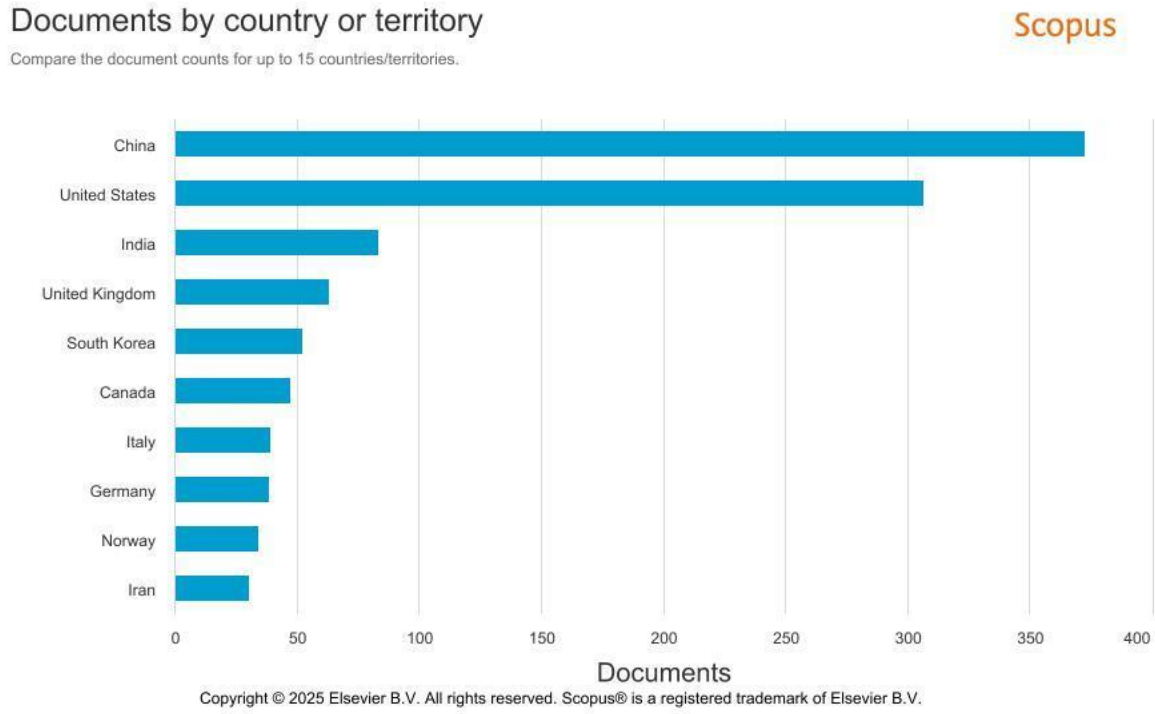

Figure 3: Top 10 Countries Based on the Number of Publications

The United States (US) follows closely with 306 publications, underscoring its longstanding engagement in disaster research and emergency management. The US possesses well-established institutions and frameworks for addressing major hazards, and its research reflects a blend of theoretical innovation and practical application. In addition, the country's interdisciplinary research culture, spanning public health, logistics, environmental science, and information systems, fosters diverse contributions to the field. While slightly behind China in volume, US-based studies often have high visibility and citation impact, influencing global discourse on emergency planning and risk mitigation.

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Table 5: Number of Publications based on Country/ Territory

Country/Territory	No. of Publication
China	372
United States	306
India	83
United Kingdom	63
South Korea	52
Canada	47
Italy	39
Germany	38
Norway	34
Iran	30

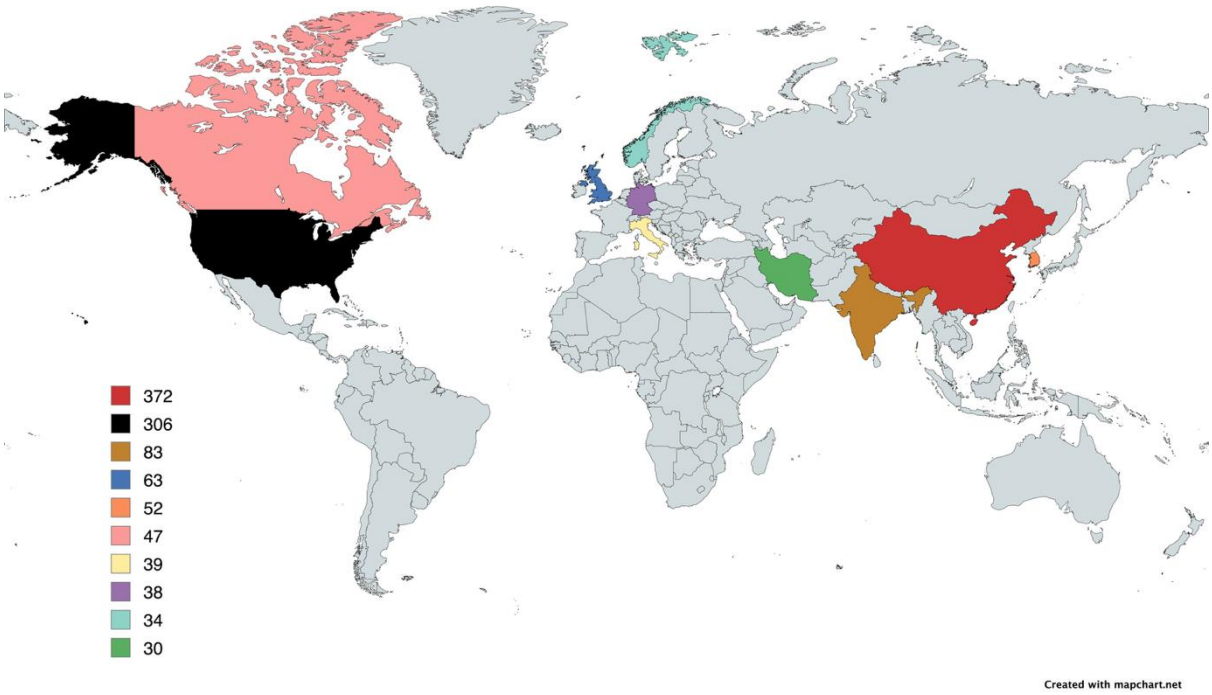

Figure 4: Mapping of the Top 10 Countries Based on the Number of Publications

Other countries present significantly lower publication volumes, with India (83), the United Kingdom (UK) (63), and South Korea (52) comprising the next tier. These nations, while contributing less in total number, still reflect active engagement, particularly through regional risk contexts, such as India's exposure to climate-induced disasters or the UK's focus on regulatory frameworks. Conversely, countries like Canada, Italy, Germany, Norway, and Iran complete the top ten, indicating a globally distributed interest, albeit with uneven research intensity. This geographic diversity suggests a growing international awareness of the importance of ERP and highlights opportunities for increased collaboration, especially between higher-output countries and those with emerging research programs.

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RQ4: What Are The Popular Keywords Related To The Study During The Last Ten Years?

The keyword "emergency response" stands out prominently in the dataset, with 599 occurrences and a total link strength of 706, far exceeding all other terms. This indicates that "emergency response" is a central concept within the analyzed literature, reflecting its broad relevance and frequent co-occurrence with other keywords. Moreover, the high total link strength suggests strong interconnectivity, meaning that this term is consistently associated with various related concepts, possibly serving as a hub in the network of research topics. This could be due to its encompassing nature, as it includes both the operational and strategic aspects of managing
emergencies.

In contrast, other keywords such as "disaster management," "disaster response," and "preparedness" appear significantly less frequently. However, they still display moderate link strengths relative to their occurrences. This pattern implies that while these topics are not as widely discussed, they maintain meaningful connections within the keyword network. In other words, their presence indicates a sustained research interest in the broader themes of disaster and emergency preparedness, emphasizing planning and systemic approaches alongside real-time responses. Additionally, terms like "safety" and "decision making" highlight concerns around risk mitigation and effective leadership during crises.

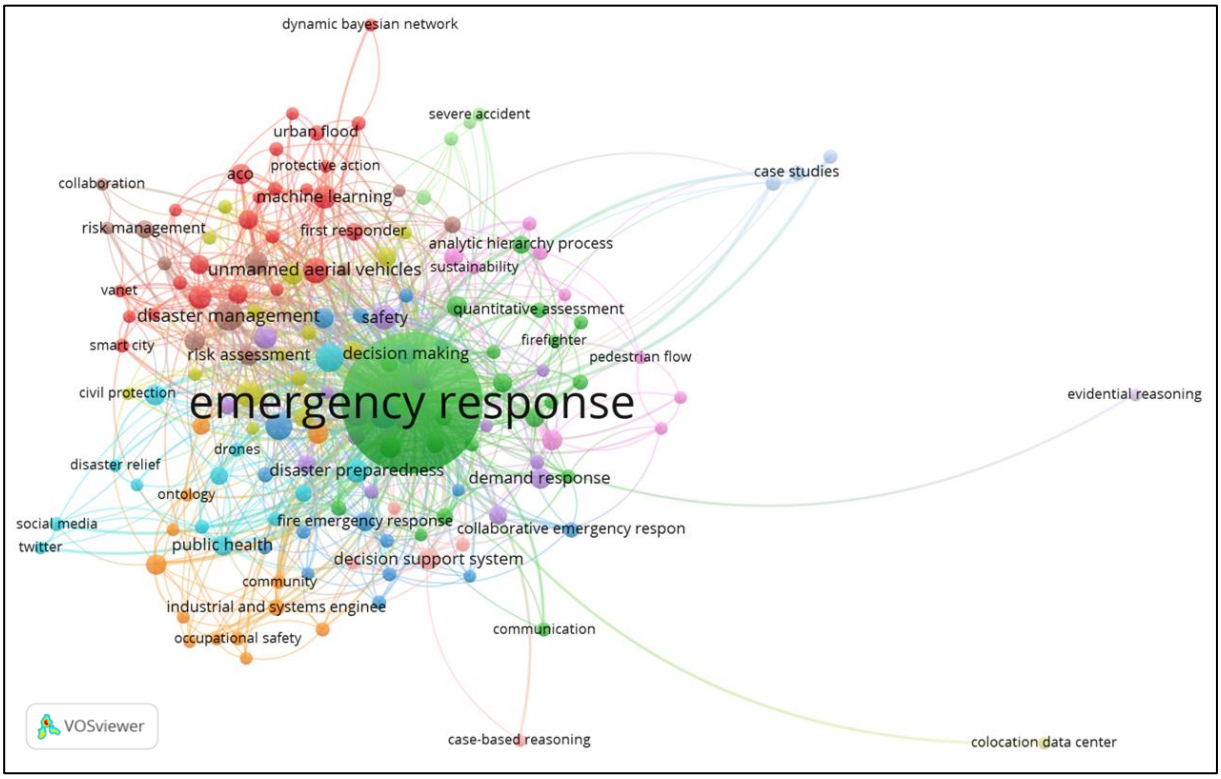

Figure 5: Most Frequently Used Keywords Over the Past Decade

Emerging technologies are also evident in the keyword landscape, with "internet of things (IoT)" and "optimization" making notable appearances. The inclusion of both "internet of things" and "iot" (potentially a redundancy due to inconsistent keyword tagging) suggests growing interest in technological integration within emergency systems. These terms signal a shift toward leveraging digital tools for improved response efficiency and resource allocation.

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Meanwhile, the keyword "information system" complements this trend, suggesting that data-driven decision-making and real-time information flow are critical research areas. Overall, the table reflects a dynamic intersection of traditional emergency management practices with innovative technological advancements.

RQ5: What Is The Co-Authorship And Collaboration Between Countries?

The data reveals that China and the US dominate the research landscape in terms of both output and citation impact. China leads with 372 documents and the highest citation count at 3474, suggesting a high research volume and significant academic influence. While producing slightly fewer documents (307), the US has a substantial citation count of 1,849, demonstrating strong engagement with its research. Both countries also have the highest total link strengths (106 for the US and 102 for China), indicating robust collaboration and integration within the global research network.

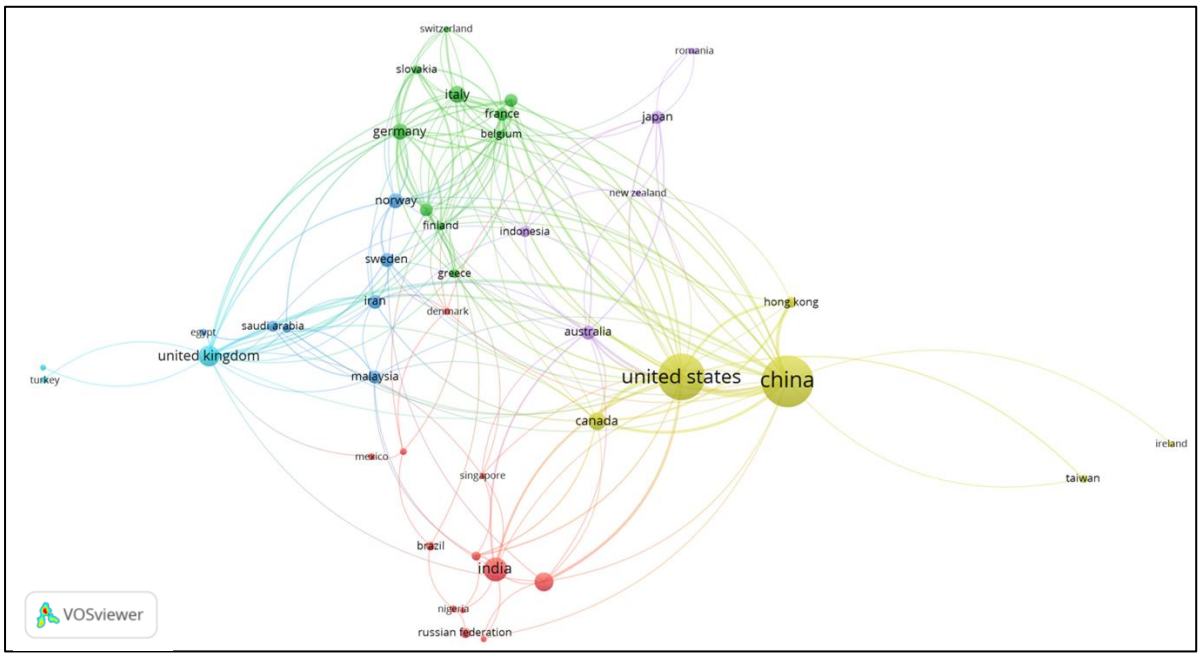

Figure 6: International Collaboration Through Co-Authorship Networks

The UK, Germany, and Canada follow in terms of influence, with fewer documents but relatively high citations and link strengths. The UK has 63 documents and 648 citations, with a link strength of 46, highlighting the quality and reach of its research. Germany, with only 38 documents, has a notably high link strength of 45, pointing to active international collaboration despite its modest output. Similarly, Canada and France maintain respectable citation numbers (533 and 247, respectively) and link strengths (39 each), placing them as key players in the research dialogue. This is especially relevant considering their smaller document counts compared to China and the US.

Emerging contributors like India, South Korea, and Hong Kong demonstrate growing involvement in the field. India has a significant number of documents (83) yet a lower link strength (16), suggesting less integration into the global citation network despite its research volume. In contrast, Hong Kong, with only 19 documents, has an impressive 426 citations and a link strength of 27, highlighting high-impact publications. Many other countries, such as Belgium, Australia, and the Netherlands, also present strong citation counts relative to their

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document numbers, indicating influential research even with smaller outputs. Meanwhile, countries like Bangladesh and the Philippines, despite contributing multiple documents, remain on the periphery with very low citations and no link strength. This reflects limited international impact or connectivity at this stage.

Conclusion

This bibliometric analysis was undertaken to examine research trends in ERP for major hazard industries, with the goal of identifying the evolution, focal points, and collaborative dynamics of scholarly contributions in this critical area. Notably, the study aimed to uncover publication patterns, influential works, key contributing countries, popular research themes, and the structure of academic collaboration across the field.

The findings revealed a consistent upward trend in publications from 2015 to 2024, reflecting increasing global attention toward enhancing preparedness for industrial hazards. China and the US emerged as the most prolific contributors, with their abundant and highly cited research indicating significant influence on global academic discourse. The analysis of frequently cited papers emphasized the prominence of logistics optimization, UAV applications, and data-driven methodologies in recent research. Furthermore, keyword co-occurrence mapping highlighted an integration of traditional safety strategies with modern technologies such as the IoT and optimization tools.

The study contributes to the field by providing a comprehensive overview of the academic landscape in ERP. It offers insight into the dominant themes and emerging areas of interest, such as digital technologies and advanced analytics, which are reshaping how emergency situations are approached and managed. Thus, by delineating the structural connections among research efforts, the analysis also underscores the significance of international collaboration and interdisciplinary approaches.

From a practical standpoint, the insights derived from this analysis may support policymakers, safety practitioners, and researchers in aligning their strategies with current trends and addressing knowledge gaps. Concurrently, enhanced awareness of global research efforts can foster more effective emergency preparedness and response frameworks, especially in high-risk industrial settings where failures can have severe consequences.

Despite the breadth of the dataset and robustness of the analytical tools employed, the study is not without limitations. The analysis was restricted to articles published in English and indexed in a single database, which may exclude relevant work published in other languages or on other platforms. Additionally, bibliometric techniques, while powerful in mapping trends, cannot fully capture the qualitative depth of each contribution. Hence, future research may benefit from integrating qualitative assessments or expanding the scope to include emerging topics and underrepresented regions.

In summary, this study demonstrates the utility of bibliometric analysis in uncovering the intellectual structure and evolving priorities in ERP for major hazard industries. The evidence underlines a dynamic and increasingly technology-driven field that continues expanding in response to longstanding and emerging global challenges. Therefore, further exploration and deeper integration of novel methodologies will be essential to enhance the effectiveness and resilience of emergency response strategies worldwide.

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