Evaluating Seismic Vulnerability and Enhancing Resilience of Road Infrastructure: A Comprehensive Bibliometric Analysis

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Evaluating Seismic Vulnerability and Enhancing Resilience of Road Infrastructure: A Comprehensive Bibliometric Analysis

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Abstract: *It is essential to conduct seismic research on road infrastructure in order to comprehend and mitigate the effects of earthquakes on transportation systems. A comprehensive bibliometric analysis is implemented in this investigation to assess the breadth and depth of scientific literature on this subject. The analysis identifies key themes, influential researchers, and collaborative networks that drive advancements in the field by systematically examining publications from 2006 to 2024. The results underscore the importance of research areas such as the development of mitigation strategies, resilience of road networks, and seismic vulnerability assessments. The temporal progression and interconnections between research topics are revealed through visualizations, such as network maps and thematic evolution diagrams. This analysis emphasizes the significance of prioritizing infrastructure resilience in order to improve disaster preparedness and response. Ultimately, the study insights will contribute to the development of a resilient and robust road infrastructure that is capable of withstanding seismic events, establishing a rich, data-driven foundation for future research and policy-making.*

Keywords: Seismic vulnerability, Road seismic resilience, Earthquake impact assessment, and Earthquake disaster

1. INTRODUCTION

Continuous monitoring and analysis of thematic focuses, collaborations, and evolving trends are essential in the dynamic and interdisciplinary field of seismic research. This not only improves our comprehension of the current research landscapes but also serves as a guide for future investigations and policy decisions. A quantitative method for evaluating the breadth and depth of scientific literature, bibliometric analysis, is essential in this process [1]. This method provides valuable insights into key themes, influential researchers, and collaborative networks that propel the field forward by methodically analyzing the extensive collection of publications.

Conducting seismic research on road infrastructure is crucial for understanding and mitigating the impacts of earthquakes on transportation systems [2]. This study implements a comprehensive bibliometric analysis to evaluate the scientific literature on this topic from 2006 to 2024. The objectives of this analysis are to identify key research themes, highlight influential researchers and collaborative networks, and uncover temporal trends in the field [3]. By providing these insights, the study aims to fill critical gaps in the existing literature and offer a foundation for future research and policy-making aimed at developing robust and resilient road infrastructure.

A rich, data-driven foundation for decision-making is established by the results of a comprehensive bibliometric analysis [4]. For instance, the complex relationships between research topics and their temporal evolution are illustrated by visualizations such as Sankey diagrams and network maps. These tools facilitate the identification of themes that have become more prominent over time and those that have declined, thereby illustrating changes in societal needs and research priorities. Furthermore, heatmaps and thematic maps highlight and categorize regions with a high level of research activity, providing a visual representation of the most densely studied and influential subjects [5].

In seismic research, where the stakes are high and the obstacles are intricate, these insights are invaluable. In addition to informing researchers about the current state of the field, they also furnish policymakers with the necessary evidence to effectively allocate funding and resources. Stakeholders can more effectively support initiatives that address the most pressing issues related to seismic vulnerability and resilience by comprehending the areas in which the research community is concentrating its efforts.

The seismic research landscape is ultimately viewed holistically through the execution of a detailed bibliometric analysis. It tracks the evolution of research over time, reveals collaboration patterns, and identifies key themes. This comprehensive comprehension is indispensable for the advancement of the field, the enhancement of collaborative endeavors, and, in the end, the enhancement of our capacity to mitigate the effects of seismic events. The results presented in the subsequent sections serve as a testament to the profound insights that have been acquired through this methodological approach, thereby elucidating the current and future directions of seismic research.

2. METHODOLOGY

Figure 1 shows a summary of the methodology for conducting a bibliometric analysis. It commences with the initial step of Start and proceeds through a series of sequential steps, which include Data Acquisition, which involves the collection of pertinent research data, and Data Processing, which entails the organization and cleaning of the data. The subsequent phase, Network Visualization, entails the development of visual representations of the data to facilitate the identification of relationships. This is succeeded by Cluster Analysis, which group themes that are similar. The evolution and patterns of the research topics are analyzed through Trend and Thematics Analysis. The process culminates

in the Discussion of Results, which includes the interpretation of the findings and the conclusion of the analysis.

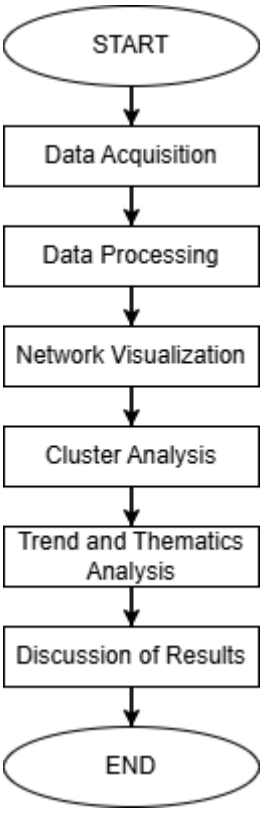

Fig. 1. Methodology of the study

2.1 Data Acquisition
The initial step entailed the collection of pertinent research articles from the Scopus database. The search was customized to encompass publications that were pertinent to seismic vulnerability, resilience, and road networks. The information that was collected encompassed keywords, abstracts, authors, publication titles, and other relevant bibliometric details.

2.2 Data Processing
It was imperative to organize and process the data for analysis after it was collected. This entailed the removal of duplicates and the establishment of consistency in the dataset. Subsequently, the bibliometric data was organized in a manner that was conducive to analysis, which involved the extraction of critical metadata, including authorship, keywords, and publication years.

2.3 Network Visualization
Network visualization tools, such as VOSviewer, were implemented to illustrate the connections between various research themes. These tools facilitated the development of co-occurrence maps, in which nodes represented keywords and edges indicated their degree of co-occurrence in the literature. The identification of central and peripheral themes within the research domain was facilitated by this visualization technique.

2.4 Cluster Analysis
The research themes were categorized into distinct groups based on their similarities using cluster analysis. Clusters of related topics were identified by analyzing the co-occurrence of keywords, which provided insights into the major areas of focus within seismic research [6]. This step was essential for comprehending the structure and organization of the research landscape.

2.5 Trend and Thematics Analysis
The temporal evolution of research themes was the focus of trend analysis. It was possible to identify emerging topics and declining areas of interest by visualizing how the focus of research shifted over different periods. This analysis facilitated comprehension of the field's dynamic nature and the evolution of research over time.

The intensity of research activity across various themes was represented through heatmap visualization [7]. This method identified topics that have garnered substantial attention by emphasizing regions with a high level of research activity. A clear visual representation of research hotspots within the field was provided by heatmaps.

To depict the progression and development of research topics over time, a Sankey diagram was developed. This diagram provided a temporal perspective on the field's development by illustrating the growth or decline of specific themes over various periods [8].

To categorize research themes according to their degree of development (density) and relevance (centrality), a thematic map was created. A comprehensive overview of the research landscape was provided by this map, which categorized themes into quadrants, including niche themes, motor themes, emerging or declining themes, and basic themes.

2.6 Discussion of Results
The final step entailed the interpretation of the visualizations to derive meaningful conclusions about the research trends and relationships. Key themes were identified, their interconnections were comprehended, and the implications of the findings for future research and policymaking were discussed.

3. RESULTS AND DISCUSSIONS

3.1 Network Analysis
The interconnected research themes related to seismic vulnerability and resilience from 2017 to 2021 are visualized in Figure 2. This map provides valuable insights into the trends and focal points of seismic research over the past few years by illustrating the relationships and co-occurrences of various keywords within the literature, thereby highlighting the central and emerging topics in the field. The temporal progression is represented by the color gradient from blue to yellow, with blue denoting older studies and yellow denoting more recent research.

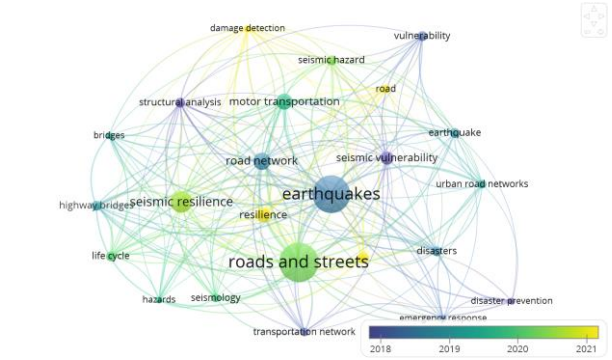

Fig. 2. Network Analysis

The pivotal roles of the central nodes in the network, including "earthquakes," "roads and streets," "seismic resilience," and "seismic vulnerability," are evident in the research landscape. The multidisciplinary nature of seismic studies is illustrated by the high degree of interconnection among these nodes. For example, the term "seismic vulnerability" is closely associated with "road," "building," and "urban road networks," indicating a comprehensive emphasis on evaluating and mitigating the susceptibility of various infrastructures to seismic events. This centrality underscores their significance in advancing research endeavors and formulating strategies to enhance resilience.

The critical role of "bridge" and "transportation network" within the network is apparent upon further examination of the map. These terms are essential for understanding the impact of seismic events on critical infrastructure. The correlations between "seismic event," "functionality," and "resilience" highlight the focus on maintaining the operationality of transportation networks during and after seismic events. This research is crucial for long-term urban planning and emergency response, aiming to reduce disruptions caused by earthquakes.

The map also highlights the development of new research themes over time. At the yellow end of the gradient, recent topics such as "damage detection," "seismic hazard," and "vulnerability" are depicted, suggesting their growing importance in contemporary research. The emergence of these themes indicates a burgeoning interest in improving and understanding the accessibility and safety of infrastructure in the context of seismic resilience. It also points to a shift towards more detailed, scenario-based risk assessments.

Another noteworthy feature is the emphasis on the social dimensions of seismic resilience, evidenced by terms such as "community" and "society." These terms emphasize the recognition of social factors in improving seismic resilience. The multidisciplinary approach necessary to tackle the complex challenges presented by seismic events is highlighted by the interconnectedness of these nodes with more technical terms. This holistic perspective is essential for developing comprehensive strategies that integrate both engineering solutions and social considerations.

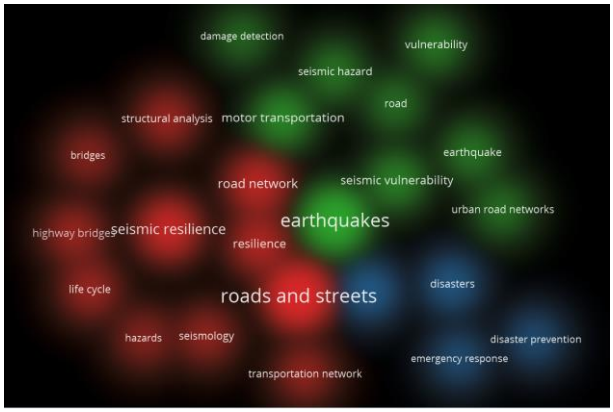

Fig. 3. Density Visualization

The density visualization shown in Figure 3 provides an in-depth representation of the intensity and thematic distribution of research activity in the field of seismic studies. The map categorizes research clusters by color, with larger and brighter clusters indicating higher research activity and denser connections among associated keywords. This visualization highlights key areas of focus and illustrates the relative importance of various topics within the research community.

At the middle of the map is the term "earthquakes," prominently positioned and brightly highlighted, signifying its central role in seismic research literature. This central node indicates that a substantial portion of research is directly concerned with earthquakes, encompassing various methodologies, case studies, and analytical approaches. Surrounding this central theme are several other important nodes, such as "roads and streets," "seismic resilience," and "seismic vulnerability," each with substantial research focus. These nodes underscore the critical significance of infrastructure resilience and vulnerability in the broader context of earthquake preparedness and response.

The visualization also reveals distinct thematic clusters: the red cluster predominantly includes themes such as "seismic resilience," "highway bridge," and "life cycle," which are crucial for understanding the long-term sustainability and structural integrity of infrastructure. The green cluster, featuring terms like "vulnerability," "seismic hazard," and "road," points to ongoing research aimed at assessing and mitigating the risks posed by seismic events to infrastructure systems. The blue cluster, containing themes such as "disasters," "emergency response," and "disaster prevention," reflects a growing focus on disaster management and preparedness, highlighting the importance of proactive measures in minimizing the impacts of earthquakes.

Notably, the visualization highlights emerging research areas such as "urban road networks" and "motor transportation," which reflect a trend towards more comprehensive studies on the impact of seismic events on transportation infrastructure in urban settings. This shift towards integrating broader urban infrastructure considerations into seismic research is indicative of an evolving focus on enhancing predictive capabilities and developing more resilient urban environments.

3.2 Identification of Influential Contributors and Trends

Fig. 4. Network Visualization of Authors

Detailed representations of the collaborative relationships among researchers in the field of seismic studies are provided in the network visualization included in Figure 4. The connections between nodes in the visualization represent co-authorship or collaborative efforts on research projects, while each node represents an individual researcher. The intensity and frequency of these collaborations are revealed by the varying colors and sizes of the nodes and clusters.

Certain researchers, including Capacci, Luca, and Biondini, Fabio, are represented in prominent green nodes at the network's core, suggesting a high degree of collaboration and connectivity with other researchers. Their central location and larger node size indicate that they are active in the research community, frequently co-authoring papers and contributing to numerous projects. This centrality emphasizes their influence and the critical role they play in the advancement of seismic research.

Another noteworthy cluster in the network is represented by the red nodes of Kassem, Moustafa Moufid, Argyroudis, Sotirios A. This cluster represents a robust collaborative relationship between these researchers, suggesting that they have co-authored numerous studies. This group is distinguished from others by its distinctive coloring, which underscores the specific research collaborations that exist within this cluster. It is imperative to engage in this type of visual differentiation to comprehend the collaborative dynamics within the broader research community and identify sub-groups.

The network also includes a number of smaller clusters and individual nodes, including Gilani, Amir, and Myagkova, Liliya, in yellow, and D'Ayala, Dina, in orange. Localized collaboration networks are indicated by these smaller clusters, in which researchers collaborate closely with a limited number of colleagues. The presence of individual nodes, such as Huang and Shuping, suggests that researchers who are less connected within the network may be conducting independent work or are beginning to establish their collaborative networks.

3.3 Thematic Analysis

The visual representation of a variety of research themes within an identified field is represented through a thematic map. The map provides a comprehensive overview of the current landscape in seismic research by categorizing topics into distinct quadrants based on their development degree (density) and relevance degree (centrality). This is achieved by plotting themes. This visual tool emphasizes the primary areas of focus, specialized niches, foundational topics, and emerging or declining themes, thereby facilitating a more profound comprehension of the research dynamics, and directing future scholarly and practical endeavors in the field.

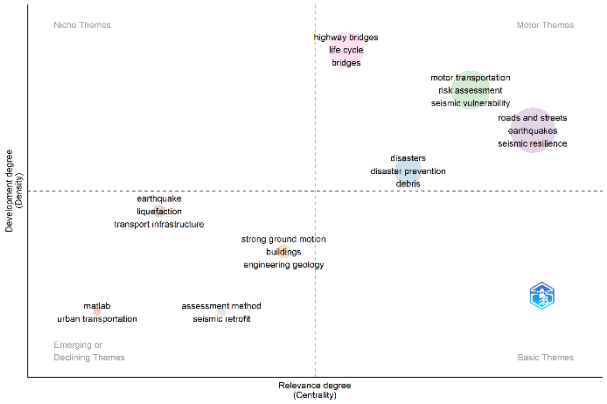

Fig. 5. Thematic Map of the Study

The thematic map shown in Figure 5 presents a comprehensive visualization of the research themes in seismic studies, which are categorized according to their degree of development (density) and relevance (centrality). Niche Themes, Motor Themes, Emerging or Declining Themes, and Basic Themes are each assigned to a quadrant on the map. This framework facilitates comprehension of the significance and positioning of numerous research topics within the broader field.

Topics such as "motor transportation," "risk assessment," "seismic vulnerability," "roads and streets," "earthquakes," and "seismic resilience" are identified in the upper-right quadrant, which is designated as Motor Themes. These themes are both central to the field and highly developed, which suggests their critical role in the advancement of seismic research. They are crucial for the advancement of the field and are distinguished by a high degree of interconnectedness. The presence of these themes in this quadrant indicates a substantial research focus on the comprehension and mitigation of the effects of seismic events on transportation infrastructure and overall resilience.

Niche Themes, which are located in the upper-left quadrant, encompass specialized topics, including "highway bridges," "life cycle," and "bridges." However, these themes are highly developed, but their centrality is lower, suggesting that they are more specialized areas within the broader research context. These topics are well-established and have a substantial body of research, but they are not as widely integrated into the central discourse of seismic studies, as indicated by their placement in this quadrant. This may indicate the existence of specialized engineering challenges and solutions that are unique to the lifecycle management of bridge infrastructure and seismic conditions.

In the lower-right quadrant, which is designated as Basic Themes, are topics such as "debris," "disaster prevention," and "disasters," among others, that are associated with the fundamental aspects of seismic events and their prevention. Although these themes are essential to the field, they may still be in the early stages of development or necessitate additional research to improve their depth, as evidenced by their high centrality but low density. This quadrant emphasizes fundamental research areas that are essential for the comprehension and management of seismic risks but necessitate further investigation to produce comprehensive solutions.

The topics in the lower-left quadrant, Emerging or Declining Themes, include "matlab," "urban transportation," "assessment method," "seismic retrofit," "earthquake," "liquefaction," and "transport infrastructure." These themes are distinguished by their low centrality and low density, which implies that they are either older topics that may be losing focus or emerging areas of research that have not yet gained significant traction. The inclusion of "earthquake" and "liquefaction" in this quadrant may suggest a shift in the research focus to more complex and integrated themes, as foundational knowledge in these areas has become more established.

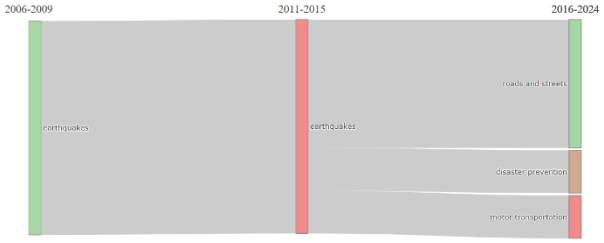

Fig. 6. Thematic Evolution

The Thematic Evolution shown in Figure 6 illustrates the progression of research themes concerning seismic activities and associated regions over three distinct time periods: 2006-2009, 2011-2015, and 2016-2024. The width of the flows indicates the relative volume of research or focus on those themes, with each segment of the diagram representing the dominant research topics within these time frames. The research focus has diversified and shifted over time, as effectively illustrated by this visualization.

From 2006 to 2009, the primary research focus was primarily on "earthquakes." This suggests that the scientific community was primarily focused on comprehending earthquakes—possibly their causes, characteristics, and immediate effects—during this period. The singular emphasis implies a foundational phase in which the primary objective was to establish a comprehensive comprehension of seismic phenomena.

The emphasis on "earthquakes" remains robust in the period from 2011 to 2015, as evidenced by the consistent width of the corresponding flow. Nevertheless, the emergence of related themes is evident, albeit they are not prominently emphasized in this section of the diagram. During this period, the central theme of "earthquakes" persisted, suggesting that, despite the continuation of foundational research, the foundation was likely being established for more specialized and applied research areas that would become more prominent in the subsequent period.

The diagram demonstrates a substantial diversification in research themes during the most recent period, which spans from 2016 to 2024. Although "earthquakes" remain a central topic, the research focus has broadened to encompass "roads and streets," "disaster prevention," and "motor transportation." This diversification suggests a transition to the development of strategies for prevention and resilience, as well as an increased awareness of the broader societal and infrastructure effects of seismic events. The terms "motor transportation" and "roads and streets" underscore a particular interest in the impact of seismic activities on transportation networks, which is essential for long-term recovery and emergency response.

The incorporation of "disaster prevention" in the 2016-2024 period indicates a heightened awareness of the importance of proactive measures over reactive responses. This change signifies a progression in the field, as the comprehension of earthquakes is now being employed to create strategies that can either prevent or reduce the effects of seismic events. This encompasses improvements in public policy, urban planning, and building codes that are designed to increase resilience.

In general, the provided Sankey Diagram effectively reflects the dynamic nature of seismic research over the past two decades. It demonstrates a clear transition from a foundational focus on earthquake knowledge to a more comprehensive approach that considers the broader effects on society and infrastructure. This development emphasizes the necessity of comprehensive strategies to improve resilience against seismic hazards and the significance of interdisciplinary research.

The dataset demonstrates the evolution of focus areas over time, revealing significant milestones in seismic research. From 2019 to 2020, the primary focus of research was on the examination of the fundamental components of seismic vulnerability and resilience, with a particular emphasis on infrastructure such as bridges and urban road networks. "Structural Health Monitoring and Assessment of Seismic Vulnerability" (2019) and "Connectivity Resilience Assessment of Urban Road Networks under Seismic Scenarios" (2020) are two notable studies that were conducted during this period. Recent studies, including "Numerical Assessment of the Seismic Vulnerability of Structures" (2023) and "Post-Earthquake Risk and Vulnerability Assessment" (2022), demonstrate substantial advancements in risk assessment methodologies, underscoring substantial advancements in the field.

3.4 Methodologies

Several methodologies stand out in the seismic research captured in the dataset. Numerical modeling is prominently used in studies like the 2023 article on numerical assessment, which employs advanced simulations to predict structural responses to seismic activity. Structural health monitoring, emphasized in the 2019 research, involves the use of sensors and real-time data collection to evaluate the integrity and vulnerability of structures during seismic events. This method provides critical insights into how infrastructure performs under

stress. Additionally, connectivity and network analysis, as seen in the 2020 study on urban road networks, assesses the resilience of transportation systems by identifying key links and nodes that require reinforcement.

3.5 Applications

The practical applications of seismic research are extensive and significant. Guidelines for the design and retrofitting of transportation systems to withstand seismic events are provided by research that concentrates on infrastructure resilience, including studies on urban road networks and earthquake-induced bridge damage. These insights are essential for urban planners and engineers who are involved in the development of infrastructure. Studies on post-earthquake risk and vulnerability assessment provide valuable knowledge for disaster preparedness and response planning, allowing authorities to more effectively allocate resources and prioritize emergency efforts. Additionally, the results of seismic vulnerability and resilience research are used to inform policy and regulatory frameworks, which in turn support the establishment of rigorous safety standards and building codes to improve community resilience.

3.6 Comprehensive Narrative of Field Progress

The dataset suggests the emergence of numerous trends in seismic research. To comprehensively address seismic challenges, there is an evident transition to interdisciplinary approaches that integrate engineering, geosciences, and urban planning. This comprehensive approach is essential for comprehending the complex connections between natural hazards and built environments. Furthermore, there is a growing emphasis on the resilience of transportation networks, as research underscores the critical role of transportation infrastructure in maintaining connectivity and mobility during and after seismic events.

3.7 Future Research

In the future, seismic research is expected to concentrate on the development of adaptive response strategies and the use of advanced simulation techniques, which will involve the integration of machine learning and artificial intelligence to more accurately predict seismic impacts. Additionally, there is an increasing acknowledgment of the necessity of community-based resilience strategies, which involve the involvement of local communities and the application of local knowledge in disaster preparedness and resilience-building initiatives. Additionally, global collaboration will be crucial for the exchange of knowledge, technologies, and best practices, resulting in more effective international strategies for the improvement of resilience and the reduction of seismic risk. There are already studies that may be used as foundation for performing the potential research topics [9,10]. The ongoing evolution seismic research are reflected in these future directions.

4. CONCLUSIONS

This comprehensive bibliometric analysis of seismic research focusing on road infrastructure has yielded critical insights into the current state and evolution of the field. The study has identified key themes, influential researchers, and collaborative networks essential for advancing knowledge and improving infrastructure resilience by systematically examining publications from 2006 to 2024. The findings underscore the importance of understanding seismic vulnerability and developing effective mitigation strategies to protect road networks during and after seismic events.

The core findings of this study reveal several key trends in seismic research that should guide future investigations. The integration of advanced methodologies, such as numerical modeling and structural health monitoring, has been pivotal in enhancing our understanding of how road infrastructure responds to seismic activities. These methodologies are crucial for developing strategies to improve the resilience of infrastructure. The study's visualizations, including network maps and thematic evolution diagrams, provide valuable insights into the temporal progression and interconnections between research topics, highlighting the dynamic nature of seismic research.

Current trends identified in this analysis emphasize the growing importance of interdisciplinary approaches that integrate engineering, geosciences, and urban planning. This comprehensive approach is essential for addressing the complex interactions between natural hazards and built environments. Additionally, there is an increasing focus on the resilience of transportation networks, which plays a critical role in maintaining connectivity and mobility during and after seismic events. This focus is crucial for long-term urban planning and emergency response.

Future research should build on these trends by concentrating on the development of adaptive response strategies and the utilization of advanced simulation techniques, including artificial intelligence and machine learning, to enhance predictive capabilities. There is also a growing recognition of the need for community-based resilience strategies, which involve local communities in disaster preparedness and leverage their knowledge to construct more resilient infrastructures. Furthermore, global collaboration will be essential for sharing knowledge, technologies, and best practices, leading to more effective international strategies for reducing seismic risk and enhancing resilience.

5. REFERENCES

[1] T. Yu, C. Zhang, X. Niu, R. Zhuang, Seismic resilience of structures research: A bibliometric analysis and state-of-the-art review, Earthquake and Structures, 25(5) (2023) 369–383.

[2] M.R.M. Noh, S. Rambat, I.S.B.A. Halim, F. Ahmad, Seismic Risk Assessment in Malaysia: A Review, Journal of Advanced Research in Applied Sciences and Engineering Technology, Penerbit Akademia Baru, December 1, 2021.

[3] J.M. Li, T.J. Wu, Y.J. Wu, M. Goh, Systematic literature review of human–machine collaboration in organizations using bibliometric analysis,

Management Decision, Emerald Publishing, October 24, 2023.

[4] F. Morante-Carballo, L. Bravo-Montero, N. Montalván-Burbano, P. Carrión-Mero, Bibliometric Analysis of Earthquake Research in America: A Comparative Study Using Web of Science and Scopus Databases, International Journal of Safety and Security Engineering, 13(5) (2023) 965–973.

[5] K. Słomska-Przech, T. Panecki, W. Pokojski, Heat maps: Perfect maps for quick reading? Comparing usability of heat maps with different levels of generalization, (2021).

[6] D.J. Ketchen, C.L. Shook, The application of cluster analysis in strategic management research: An analysis and critique, Strategic Management Journal, 17(6) (1996) 441–458.

[7] M. Hanzl, A. Geerse, L. Guschl, R. Dewan, Urban metabolism and land use optimization: In quest for modus operandi for urban resilience, in: Understanding Disaster Risk: A Multidimensional Approach, Elsevier, 2020, pp. 109–130.

[8] R.C. Lupton, J.M. Allwood, Hybrid Sankey diagrams: Visual analysis of multidimensional data for understanding resource use, Resources, Conservation and Recycling, 124 (2017) 141–151.

[9] Z.M. Taqiuddin et al, IOP Conf. Ser.: Earth Environ. Sci. 62 (2017) 012015.

[10] C. Chen, L.K. Lin, The Risk Assessment Management of Disaster Prevention on Roads, in: International Exchange and Innovation Conference on Engineering and Sciences, Kyushu University, 2022, pp. 438–443.