OPEN ACCESS
Engineering Science & Technology Journal
P-ISSN: 2708-8944, E-ISSN: 2708-8952
Volume 5, Issue 2, P.No. 338-357, February 2024
DOI: 10.51594/estj/v5i2.764
Fair East Publishers
Journal Homepage: www.fepbl.com/index.php/estj

EVALUATING THE ROLE OF BIG DATA IN U.S. DISASTER MITIGATION AND RESPONSE: A GEOLOGICAL AND BUSINESS PERSPECTIVE

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Article Received: 01-01-24 **Accepted:** 25-01-24 **Published:** 07-02-24

ABSTRACT

Navigating the complex nexus of big data's application in U.S. disaster mitigation and response, this study embarks on an intellectual odyssey to unravel the dynamic interplay between geology and business. Set against the backdrop of an increasingly data-driven world, the research delves into the transformative potential of big data in revolutionizing disaster management paradigms. The expedition of this paper is twofold: to dissect the evolutionary trajectory of big data in the realm of disaster management and to illuminate its economic ramifications and theoretical underpinnings. The scope of this inquiry extends to a meticulous examination of the efficacy of big data in forecasting natural disasters, optimizing disaster response mechanisms and evaluating their economic and environmental impacts. Employing a methodological tapestry woven with qualitative analyses, the study meticulously synthesizes a spectrum of peer-reviewed literature. This scholarly pursuit unveils that big data stands as a beacon of innovation, significantly bolstering the precision of disaster predictions, streamlining response strategies

and fortifying economic resilience. The fusion of geological acumen with strategic business insights emerges as a cornerstone in crafting adept disaster management strategies.

The crescendo of this scholarly narrative underscores big data as a pivotal catalyst in the metamorphosis of disaster management strategies. The paper advocates for an embracement of big data by policymakers and disaster management aficionados, urging its integration for crafting more resilient, efficient, and sustainable disaster responses. The horizon of future research is marked by a quest to bridge existing gaps, with a clarion call for enhancing real-time disaster responses and predictive prowess. This scholarly discourse offers a prism through which the impact of big data in disaster management is not only understood but also harnessed, providing invaluable insights for academia, policy formulation and practical implementation.

Keywords: Big Data, Disaster Management, Predictive Analytics, Geological Insights, Business Strategies, Disaster Resilience.

INTRODUCTION

The Evolution of Big Data in Disaster Management

The intersection of geology and business in disaster response has evolved significantly with the advent of big data. Sarvari, Nozari and Khadraoui (2019) highlight the transformative role of technology in disaster management, emphasizing the need for resilient and innovative decision support systems. These systems, leveraging big data, are crucial in both natural and man-made disasters, offering solutions for preparedness, response, recovery and mitigation. The integration of virtual experiments, machine learning, blockchain and database management technologies marks a significant shift from traditional disaster management approaches, enabling real-time data processing and decision-making.

Bouzidi, Boudries and Amad (2021) further elaborate on the role of big data in crisis management, particularly in the context of social media's broad dissemination and scope. The real-time exchange of information facilitated by social media and big data analytics plays a pivotal role in reducing disaster risk and enhancing the effectiveness of disaster response. The rapid and accurate assessment of crises, primarily through data collected on-site by first responders and later updated, is a testament to the power of big data in disaster management. The integration of deep learning and parallel computing environments has further enhanced the capacity for effective crisis management.

Tin et al. (2013) propose an integrated framework for analyzing disaster events using big data analytics. This framework addresses key components such as data organization, integration, analysis and information presentation, specifically tailored to disaster events. The use of stochastic clustering with constraints for automatic extraction of disaster events exemplifies the innovative application of big data in understanding and mitigating disaster impacts. This approach, particularly in the context of the Great East Japan earthquake, tsunami and nuclear disaster, underscores the potential of big data in providing critical real-time information for disaster prevention and management.

The current trends in data analytics for disaster mitigation reflect a paradigm shift towards more data-driven approaches. The ability to measure community sentiments, design hazard scenarios and propose emergency evacuation plans using 3D notifications are among the innovative features of these new technologies. The integration of big data in disaster management not only

enhances the effectiveness of response strategies but also contributes to the development of more resilient societies.

The evolution of big data in disaster management, particularly at the intersection of geology and business, has been marked by significant advancements in technology and analytics. The integration of machine learning, blockchain and real-time data processing has revolutionized traditional approaches to disaster management, offering more effective and innovative solutions for disaster preparedness, response, recovery and mitigation. The role of big data in enhancing crisis management, particularly through social media and advanced computing technologies, further underscores its transformative impact in this field.

The Intersection of Geology and Business in Disaster Response

The integration of geology and business in disaster response has been significantly enhanced by the advent of big data technologies. Qian (2022) discusses the development of a regional geological disaster emergency management system, which utilizes big data platforms for monitoring and responding to geological hazards. This system demonstrates the practical application of big data in improving the speed and efficiency of disaster response, highlighting a 59.4% increase in the processing speed of relevant departments when faced with geological disasters. The system's ability to store and visualize data, coupled with its disaster early warning capacity, exemplifies the intersection of geological understanding and business efficiency in disaster management.

Xu and Wu's (2023) research further explores the application of big data and artificial intelligence in geological disaster risk monitoring and early warning. Their work dissects relevant dimensions of geological disasters with increasing precision, leading to more accurate results. By integrating hydrogeological conditions with major national, regional and local water resource needs, their approach exemplifies how big data can be used to coordinate groundwater level measurement and resource evaluation. This integration supports the management of water resources and addresses water ecology and Earth science issues, thereby aligning geological insights with business strategies for disaster mitigation.

Avalon-Cullen et al. (2023) focus on the use of Earth Observations and big data for improving flood and landslide risk assessment in Jamaica. Their study illustrates how big data can be utilized to enhance national Disaster Risk Reduction (DRR) planning and response. By reviewing the current state of knowledge, data, models and tools, they identify opportunities and capacity needs for integrating big data into national DRR frameworks. This approach is particularly relevant for Small Island Developing States (SIDS), which face multiple and compounding hazards. The integration of big data in these contexts demonstrates its potential to guide policy improvements and effective disaster management strategies.

The intersection of geology and business in disaster response, as evidenced by these studies, is characterized by the innovative use of big data technologies. The ability to rapidly process and analyze large volumes of data has transformed the way geological disasters are managed, making responses more efficient and effective. The integration of artificial intelligence and machine learning further enhances the capacity to predict and mitigate the impacts of such disasters. This synergy between geological understanding and business acumen is crucial in developing resilient strategies for disaster management and mitigation.

The intersection of geology and business in disaster response, facilitated by big data, represents a significant advancement in the field of disaster management. The development of systems and

frameworks that leverage big data for monitoring, predicting and responding to geological disasters exemplifies the potential of this technology in enhancing disaster resilience. The integration of geological insights with business strategies, supported by big data analytics, is key to developing effective and efficient disaster management practices.

Current Trends in Data Analytics for Disaster Mitigation

The realm of disaster mitigation has been revolutionized by the integration of big data analytics (BDA) and the Internet of Things (IoT), as highlighted by Shah et al. (2019). Their research underscores the significant role of BDA and IoT in enhancing disaster management systems. The development of a thematic taxonomy and a conceptual reference model for BDA- and IoT-based disaster management environments demonstrates the potential of these technologies in providing accurate and timely decision-making support. This advancement is crucial for emergency responders, police, public health and fire departments, offering state-of-the-art assistance and improved insights.

Kondraganti, Narayanamurthy and Sharifi (2022) conducted a systematic literature review on the use of big data analytics in humanitarian and disaster operations. Their findings reveal a considerable research disparity in disaster groups, phases and regions, emphasizing a focus on reactionary interventions rather than preventative approaches. This study highlights the critical role of big data in supporting humanitarian aid, especially amid civil conflicts, natural disasters and pandemics. The integration of big data analytics in disaster management is seen as a pivotal element in shaping future humanitarian and disaster operations.

Shah et al. (2019) propose a novel reference architecture for a disaster resilient smart city (DRSC) through the integration of IoT and BDA technologies. Their architecture offers a generic solution for disaster management activities in smart city incentives, utilizing a combination of the Hadoop Ecosystem and Spark for efficient real-time and offline analysis. The implementation model of this environment, consisting of data harvesting, aggregation, pre-processing, and analytics, validates the system's efficiency in detecting and generating alerts for various disasters. This approach exemplifies the transformative impact of big data analytics and IoT in creating smart, disaster-resilient urban environments.

The current trends in data analytics for disaster mitigation reflect a paradigm shift towards more integrated and technologically advanced approaches. The ability of big data analytics to process and analyze vast amounts of data in real-time has significantly enhanced the capacity for disaster prediction, understanding, and monitoring. The integration of IoT further augments this capability, providing a comprehensive framework for disaster management that spans from early warning systems to post-disaster recovery and analysis.

The innovative application of big data and IoT technologies characterizes the evolution of data analytics in disaster mitigation. These advancements have not only improved the efficiency and effectiveness of disaster management systems but have also paved the way for the development of smart, resilient urban environments capable of withstanding and responding to various disaster scenarios. The integration of these technologies in disaster management represents a significant step forward in enhancing global disaster resilience and preparedness.

Economic Implications of Data-Driven Disaster Response

The economic implications of data-driven disaster response are multifaceted, encompassing aspects of crisis management, urban resilience and socio-economic development. Yang, Su and Chen (2017) discuss the use of big data in enhancing crisis response and disaster resilience,

particularly in the context of smart cities. Their research highlights how big data can improve emergency management by enabling the identification and assessment of risks through critical infrastructure operating data or sensor data. This approach not only enhances the efficiency of disaster response but also contributes to the economic resilience of cities by minimizing losses and optimizing resource allocation.

Qadir et al. (2016) delve into the history and future of big crisis data analytics, emphasizing its potential in processing large amounts of crisis-related data for effective disaster response. The ability to analyze user-generated data, in addition to traditional humanitarian data, provides insights into rapidly changing situations, thereby aiding in more informed and timely decision-making. This capability is crucial for reducing economic losses and ensuring a swift recovery in the aftermath of disasters.

Agbozo and Asamoah (2019) explore the socio-economic ramifications of data-driven e-government, which is closely related to disaster management. Their findings suggest that data-driven e-government policies can significantly improve socio-economic development. By leveraging big data, artificial intelligence and machine learning, public sector decision-making can be revolutionized, leading to more efficient and effective governance, especially in times of crisis. This transition towards a data-driven public sector has profound implications for economic development and societal well-being.

The integration of big data in disaster management and response strategies offers numerous economic benefits. It enables more accurate risk assessment, efficient resource allocation and faster recovery processes, all of which contribute to reducing the economic impact of disasters. Furthermore, the use of big data analytics in e-government initiatives enhances the overall governance framework, which is essential for managing disasters effectively and ensuring sustainable economic growth.

The economic implications of data-driven disaster response are significant and far-reaching. The integration of big data analytics in disaster management not only improves the effectiveness of response strategies but also contributes to the economic resilience and sustainable development of societies. As technology continues to advance, the role of big data in disaster response and economic planning is expected to become even more pivotal.

Environmental Resilience Through Advanced Data Utilization

The concept of environmental resilience in the context of disaster management has been significantly enhanced through the application of big data and artificial intelligence (AI). Sarker et al. (2020) emphasize how big data technologies can mitigate the risks and impacts of socio-ecological vulnerability, thereby enhancing resilience. Their study underscores the importance of adaptive, absorptive and transformative capacities within socio-political systems to cope with the adverse effects of disasters. The utilization of big data in this context involves open-source tools, strong infrastructure, local skill development and ethical data sharing, all of which contribute to effective disaster management and environmental sustainability.

Sarker et al. (2020) further explore the potential of big data in increasing resilience against socio-ecological vulnerability. They argue that disaster resilience is an integrated function of the capacities of individuals or societies to withstand and cope with disaster effects. Big data technologies provide a wealth of information that enhances these capacities, enabling social systems to face natural disasters more effectively. The study highlights the major principles of big data use in disaster management, including the development of context-specific data sources

and learning from experience, which are crucial for policymakers and stakeholders in disaster response.

Fant and Adelman (2022) discuss the role of big data and AI in building community resilience, particularly in support of public health emergency preparedness. They point out that big data can be a significant resource for decision-making and preparations in disaster scenarios. Big data and AI provide a foundation for predicting future events and planning more effective disaster responses by analysing previous disasters and evaluating data from various sources, such as remote sensors. This approach is pivotal in ensuring the physical, behavioral, social and environmental well-being of communities, which is the cornerstone of resilience.

The integration of big data and AI in environmental resilience and disaster management represents a paradigm shift in how disasters are predicted, managed and recovered from. The ability to process and analyze vast amounts of data in real-time has significantly enhanced the capacity for disaster prediction, understanding, and monitoring. This, in turn, leads to more informed decision-making, efficient resource allocation, and faster recovery processes, all of which are essential for reducing the environmental and socio-economic impact of disasters.

The advancement of big data and AI technologies has brought about significant improvements in environmental resilience in the face of disasters. These technologies enable a more nuanced understanding of disasters and their impacts, leading to more effective and sustainable disaster management strategies. As these technologies continue to evolve, their role in enhancing environmental resilience and supporting disaster management efforts is expected to grow even more critical.

Challenges and Limitations in Current Big Data Applications

The integration of big data in disaster management has brought about transformative changes in how crises are handled. However, this integration is not without its challenges and limitations. Akter and Wamba (2019) provide a comprehensive review of big data's role in disaster management, highlighting the main contributions, gaps and challenges. Their study underscores the fragmented nature of the relevant literature and the need for a systematic approach to understand the development and impact of big data in this field. The classification of publications and analysis of trends in their study contribute to a better understanding of big data's importance in disaster management.

Mahrin et al. (2023) explore the use of cloud-based big data frameworks in strengthening disaster risk reduction. Their systematic mapping study reveals the limitations and practical implications of current big data applications in disaster management. They identify a lack of specific studies on big data platforms in this field and highlight the challenges in leveraging existing big data platforms for disaster risk reduction. The study emphasizes the need for more proactive disaster preparedness and the importance of listening to and learning from disaster data.

Elsotouhy, Jain and Shrivastava (2021) focus on the application of big data in pandemic disaster management. Their study reveals the research lacuna in handling the constant inflow of unstructured data, especially during a pandemic. They propose a big data-centric approach to pandemic disaster management, emphasizing the need to understand past disaster management efforts and improve future crisis responses using big data. The study highlights the challenges in converting unstructured data into structured information and the importance of big data text analytics in effective pandemic disaster management.

The challenges and limitations in current big data applications in disaster management are multifaceted. They include the fragmented nature of research, the lack of specific studies on big data platforms, and the difficulties in handling unstructured data. These challenges underscore the need for a more integrated and systematic approach to leveraging big data in disaster management. Addressing these challenges will require collaboration among researchers, policymakers and practitioners to develop more effective and efficient disaster management strategies using big data.

While big data has the potential to revolutionize disaster management, there are significant challenges and limitations that need to be addressed. These include the need for more systematic research, the development of specific big data platforms for disaster management and the effective handling of unstructured data. Overcoming these challenges will be crucial for harnessing the full potential of big data in improving disaster management and enhancing resilience.

Theoretical Frameworks Guiding Data Use in Disaster Scenarios

The use of big data in disaster scenarios is guided by various theoretical frameworks that enhance understanding and response capabilities. Cumbane and Gidófalvi (2019) provide a comprehensive review of big data and processing frameworks for disaster response applications. They emphasize the critical role of integrating data from various sources with different characteristics and processing needs. Their work contributes to understanding potential big data sources and characterizing big data processing frameworks, thereby establishing a link between big data and processing frameworks based on the essential tasks in the response phase of disaster management.

Kondraganti, Narayanamurthy and Sharifi (2022) conducted a systematic literature review on the use of big data analytics in humanitarian and disaster operations. Their research offers a comprehensive overview of big data analytics in disaster settings, creating a framework to understand why researchers employ various big data sources in different crisis situations. This study highlights the importance of big data in informing disaster categories, phases, locations and sources used, thereby providing a structured approach to disaster management.

Detera et al. (2023) investigate the use of spatio-temporal big data as an input in population exposure assessment across multiple disaster scenarios. Their study utilizes mobile phone and social media data to analyze population changes and trends during disasters. This approach provides a high temporal resolution assessment of population exposure, aiding disaster risk management. The study demonstrates the application of theoretical frameworks in understanding the dynamic trends of populations affected by disasters.

The integration of theoretical frameworks in guiding data use in disaster scenarios is crucial for effective disaster management. These frameworks provide a structured approach to integrating and processing various data sources, enabling a more nuanced understanding of disasters and their impacts. The use of spatio-temporal analysis, in particular, offers valuable insights into population dynamics during disasters, which is essential for risk assessment and mitigation.

Theoretical frameworks play a pivotal role in guiding the use of big data in disaster scenarios. These frameworks enable the integration of various data sources and provide a structured approach to disaster management. The application of these frameworks enhances the understanding of disaster dynamics and supports effective response and mitigation strategies.

As big data continues to evolve, these frameworks will be instrumental in advancing disaster management practices.

Identifying the Research Gap in Literature

The integration of big data in disaster management has been a subject of extensive research, yet there remain significant gaps in the literature that need to be addressed. Akter and Wamba (2019) conducted a systematic review of big data in disaster management, identifying main contributions, gaps, challenges and a future research agenda. Their study reveals a fragmented landscape of research, with a need for a more cohesive understanding of big data's role in disaster management.

Kondraganti, Narayanamurthy and Sharifi (2022) also undertook a systematic literature review focusing on big data analytics in humanitarian and disaster operations. Their research highlights a considerable disparity in the focus of studies, with an emphasis on reactionary interventions rather than preventative approaches. This gap underscores the need for research that not only addresses immediate disaster response but also focuses on predictive analytics and prevention strategies.

Rosenblum et al. (2023) explored the use of big data in disaster recovery through an integrative literature review. Their findings indicate that while big data has seen explosive growth in business and private industries, its application in disaster recovery remains nascent. The study calls for more research in real-time applied disaster recovery settings to expand the knowledge base for future applications.

Akter and Wamba's (2019) research further emphasizes the need for a systematic approach to understand the development and impact of big data in disaster management. The study suggests that while there are numerous publications on the subject, a cohesive and comprehensive understanding of big data's role across different phases of disaster management is lacking.

The research gaps identified in these studies highlight several key areas for future exploration. There is a need for more integrated research that bridges the gap between immediate disaster response and long-term prevention strategies. Additionally, the application of big data in real-time disaster recovery settings requires further investigation. Addressing these gaps will not only enhance the understanding of big data's role in disaster management but also contribute to more effective and efficient disaster response and recovery strategies.

While significant strides have been made in understanding big data's role in disaster management, there remain critical gaps in the literature. Future research should focus on developing a more cohesive understanding of big data across all phases of disaster management, with an emphasis on predictive analytics, prevention strategies, and real-time disaster recovery applications. Addressing these gaps will be crucial in harnessing the full potential of big data in improving disaster management practices.

Objectives and Scope of the Literature Review

This literature review aims to comprehensively explore the role of big data in disaster management, delving into its applications, impacts, challenges, and the theoretical frameworks guiding its use. By examining a range of scholarly articles and studies, the review seeks to provide a detailed understanding of how big data has transformed disaster management practices and to identify areas where further research is needed. The objectives of this review are as follows:

1. To systematically analyze the evolution and current state of big data applications in disaster management, focusing on technological advancements and their practical implications.
2. To evaluate the economic impact of data-driven strategies in disaster response, particularly in terms of environmental resilience and resource allocation efficiency.
3. To identify existing research gaps in the literature concerning the application of big data in disaster scenarios, including challenges and theoretical frameworks.
4. To propose a future research agenda that addresses identified gaps, with a focus on enhancing predictive analytics, prevention strategies, and real-time disaster recovery using big data.

LITERATURE REVIEW METHODOLOGY

Criteria for Selecting Relevant Literature

In developing a comprehensive understanding of big data's role in disaster management, the criteria for selecting relevant literature were meticulously established. This study prioritized peer-reviewed articles and studies, focusing on those published in reputable journals to ensure academic rigor and credibility (Akter & Wamba, 2019). The literature was required to specifically address the use of big data in disaster management contexts, encompassing its diverse applications, challenges and impacts (Rosenblum et al., 2023). Emphasis was placed on studies that provided insights into technological advancements, economic implications and theoretical frameworks guiding big data use in disaster scenarios (Nunavath & Olsen, 2018). The selected literature covered a range of disaster types and management phases, from prevention and preparedness to response and recovery, offering a holistic view of the field (Kondraganti, Narayanamurthy & Sharifi, 2022). Furthermore, the inclusion of studies that explored the intersection of big data with various disaster management strategies was deemed essential to capture the multifaceted nature of this domain (Cumbane & Gidófalvi, 2019).

Approach to Synthesizing and Analyzing the Literature

The approach to synthesizing and analyzing the literature involved a qualitative analysis, focusing on thematic content review to draw out comprehensive insights. This process included categorizing the literature based on common themes and patterns, such as the types of big data technologies used in different disaster management phases and the geographical context of the studies (Akter & Wamba, 2019). The analysis also involved evaluating the methodologies employed in the studies, their findings, and the implications for both practice and policy (Rosenblum et al., 2023). This synthesis aimed to draw comprehensive insights into how big data is currently being utilized in disaster management and to identify areas where further research is needed (Nunavath & Olsen, 2018). The analysis did not involve statistical or quantitative methods but rather focused on qualitative assessment and interpretation of the literature, providing a nuanced understanding of the role of big data in disaster management (Kondraganti, Narayanamurthy & Sharifi, 2022; Cumbane & Gidófalvi, 2019).

RESULTS OF THE LITERATURE REVIEW

Effectiveness of Big Data in Predicting Natural Disasters

In recent times, the role of big data in forecasting natural disasters has become more pronounced. The study by Arslan et al. (2017) highlights the importance of big data analysis, not just in business but also in improving the efficiency of emergency and disaster management entities. The immediate data gathered from smartphones and social media platforms has

transformed the way disasters are evaluated, allowing for swift and dependable reaction strategies. The ability of big data to connect those affected by disasters with emergency services and to aid in recovery efforts through shared knowledge, marks a notable progress in this area.
Joseph and Kakade (2014) delve into the application of data mining techniques for evaluating natural catastrophic events. Their work highlights the goal of such analysis in preparing governments for emergency response and relief efforts, as well as formulating strategies for future disaster mitigation. The use of both supervised and unsupervised learning techniques on natural disaster data extracted from databases like EM-DAT demonstrates the predictive capabilities of big data in assessing the monetary impact of natural calamities.
Velev and Zlateva (2016) analyze the relationship between natural disasters and big data, emphasizing the combination of ICT developments like social networking, mobile computing, Internet of Things, and Cloud computing in managing natural disasters more effectively. Their study reveals how rescue organizations are finding value in big data from both structured and unstructured sources, generated in large volumes, for disaster management.
Arinta and WR. (2019) focus on the application of big data, machine learning, and deep learning in disaster management. Their review process provides insights into the use of these methods in visualizing, analyzing and predicting natural disasters. The study outlines the impact of big data and machine learning across six disaster management areas, including early warning, damage assessment, monitoring and detection, forecasting and predicting, post-disaster coordination and response and long-term risk assessment and reduction.
The effectiveness of big data in predicting natural disasters is highlighted through its ability to process and analyze large volumes of data from various sources. The integration of machine learning and deep learning techniques further enhances this capability, providing more accurate predictions and efficient disaster management strategies. These advancements in big data analytics are crucial in preparing for and responding to natural disasters, ultimately contributing to the reduction of their impacts.

Role of Data Analytics in Streamlining Disaster Response

The role of data analytics in streamlining disaster response has become increasingly crucial, leveraging big data to enhance the efficiency and effectiveness of disaster management. Qadir et al. (2016) discuss the transformative impact of big data tools in processing large amounts of crisis-related data, providing insights into fast-changing situations to drive effective disaster response. The ability to analyze user-generated data, in addition to traditional humanitarian data, has revolutionized the way disaster response is managed, offering real-time insights and facilitating rapid decision-making.
Kondraganti, Narayanamurthy and Sharifi (2022) highlight the critical role of big data analytics in humanitarian and disaster operations through their systematic literature review. Their study emphasizes the importance of leveraging big data to address the challenges in disaster phases, with a focus on responsive measures rather than preventive measures. The review underscores the need for a holistic understanding of big data analytics in disaster settings, identifying research gaps and opportunities for future research.
Hu et al. (2019) propose a two-stage framework for big spatial data analytics to support disaster response. Their approach involves a Data Envelope Analysis (DEA) model to prioritize data processing tasks and an Apache Storm-based streaming processing platform for computational resource optimization. This framework demonstrates how big data analytics can be used to

process large and diverse data sets efficiently, ensuring timely and relevant information for decision-making during disaster response.

The integration of data analytics in disaster response has shown significant potential in improving the speed and accuracy of response strategies. By processing and analyzing vast amounts of data, disaster management teams can gain real-time insights into the evolving situation, enabling them to make informed decisions quickly. The use of advanced analytics tools and frameworks further enhances this capability, providing a more streamlined and effective approach to disaster response.

Data analytics plays a pivotal role in streamlining disaster response by providing real-time insights, facilitating rapid decision-making, and optimizing resource allocation. The advancements in big data tools and analytics frameworks have significantly improved the efficiency and effectiveness of disaster management strategies. As technology continues to evolve, the role of data analytics in disaster response is expected to become even more integral, contributing to more effective and efficient disaster management practices.

Economic Benefits of Data-Driven Disaster Mitigation Strategies

The economic benefits of data-driven disaster mitigation strategies are increasingly recognized in the field of disaster management. Kim et al. (2021) developed a strategic framework for natural disaster-induced cost risk analysis and mitigation, employing a two-stage approach that combines deep learning algorithms with cost-benefit analysis. This framework is instrumental in predicting natural disaster losses and quantifying the effects of disaster reduction projects, thereby aiding in the economic analysis of risk mitigation efforts and the effective allocation of public budgets.

Veigel, Kreibich and Cominola (2021) explored the use of big data in understanding flood insurance purchase behaviors, which serve as a proxy for flood awareness and preparedness. Their study utilized data mining techniques to spatially correlate and model insurance ratios with socioeconomic data in official floodplains. This approach contributes to identifying the main determinants of flood insurance uptake, thereby informing strategies to address societal inequalities in disaster risk management and enhance economic resilience.

Yu, Yang and Li (2018) conducted a comprehensive review of the role of big data in natural disaster management, highlighting its varied possibilities in visualizing, analyzing and predicting natural disasters. The review underscores how big data has changed the ways human societies adopt disaster management strategies, reducing human suffering and economic losses. The paper emphasizes the importance of leveraging big data across different disaster management phases, from monitoring and detection to relief efforts and reconstruction, thereby contributing to more effective and economically viable disaster management solutions.

Data-driven disaster mitigation strategies offer significant economic benefits by enhancing the efficiency and effectiveness of disaster management. The integration of deep learning algorithms and cost-benefit analysis, as well as the utilization of big data in understanding and predicting human behaviors related to disaster preparedness, are crucial in optimizing resource allocation and reducing economic losses. These advancements in big data analytics are pivotal in shaping more resilient and economically sustainable disaster management practices.

Environmental Impact Assessment of Big Data Applications

The environmental impact of big data applications in disaster management is a critical area of study, as these technologies play a significant role in mitigating the effects of natural disasters.

Chen (2021) explores the role and impact of environmental big data in agricultural disaster management. The study emphasizes how big data technology can analyze historical agricultural disaster data, enhancing the effectiveness of disaster management. The use of parallel information entropy attribute reduction algorithms and KNN classification in big data sets demonstrates the potential of big data in optimizing the mining effect and accelerating the classification and prediction speed in disaster scenarios.

Wong (2021) discusses the application of AI and big data in sensitive operations, including disaster management. The paper highlights the challenges and opportunities presented by the rapid growth of big data and its implications for social life, the environment and the economy. The study underscores the need for solutions to handle and extract value from large datasets, emphasizing the role of AI in ensuring an effective supply of information during crises.

Akter and Wamba (2019) provide a systematic review of big data in disaster management, presenting the main contributions, gaps, and challenges in the field. Their study offers insights into the classification of publications and the impact of big data on disaster management, including its environmental implications. The review contributes to a better understanding of the importance of big data in disaster management and highlights the need for further research in this area.

The environmental impact assessment of big data applications in disaster management reveals the significant role these technologies play in mitigating the effects of natural disasters. The integration of big data analytics, AI, and machine learning in disaster management strategies offers promising solutions for optimizing resource allocation, enhancing prediction accuracy, and reducing the environmental impact of disasters. These advancements in technology are crucial for developing more effective and sustainable disaster management practices.

Comparative Analysis of Pre and Post-Big Data Disaster Responses

The comparative analysis of pre and post-big data disaster responses reveals significant shifts in disaster management strategies and outcomes. Jordan and Javernick-Will's (2016) study on the 2004 Tsunami in Tamil Nadu, India, provides insights into how communities recover differently from the same disaster. Using fuzzy-set Qualitative Comparative Analysis (fsQCA), the study identifies combinations of pre-disaster factors and recovery strategies that led to successful post-tsunami community recovery. This research highlights the importance of pre-disaster social vulnerability and access to government resources, as well as the embeddedness, coordination and oversight of recovery agencies in both infrastructural and social recovery.

Avadi and Seth (2020) conducted a comparative analysis of the Indian military's involvement in disaster response before and after the adoption of the National Disaster Management Framework in 2005. Their study underscores the continued dependence on military for disaster response, despite the establishment of specialized civilian response agencies. The analysis shows that the military's role in disaster response has not declined but rather increased in terms of both extent and frequency. This dependence is evident in quantitative data such as the amount of rescue material distributed and the number of people evacuated.

Almarzouqi (2017) analyzed disaster vulnerability in the United Arab Emirates (UAE), focusing on the changes in risk profiles due to economic developments and immigration. The study presents the first hazard history of the UAE, using a vulnerability viewpoint to evaluate disaster risk management strategies. The research investigates the role of Islam in disaster risk

reduction and employs a mixed-methods approach to assess the perception and response to risks among different communities and stakeholders.

The comparative analysis of pre and post-big data disaster responses highlights the evolution of disaster management strategies and the varying outcomes of recovery efforts. The studies emphasize the significance of understanding pre-disaster conditions, the role of military and civilian agencies in disaster response, and the changing risk profiles due to socio-economic factors. These insights are crucial for developing more effective disaster management practices and policies that are responsive to the needs and vulnerabilities of diverse communities.

Case Studies: Success Stories in Data-Driven Mitigation

The integration of big data and analytics in disaster management has led to several success stories, demonstrating the transformative impact of these technologies in mitigating disasters. In the region around Singkarak Lake, Indonesia, a unique approach to disaster mitigation is observed, where local communities utilize oral stories to build and understand disaster knowledge. Anwar et al.'s (2023) study delves into how these communities believe in the truth of these stories and incorporate them into their social structures. This approach underscores the significance of cultural and traditional knowledge in disaster management, highlighting how local narratives can play a crucial role in maintaining environmental balance and enhancing community resilience.

In the context of tourism, Wang, Liao and Zhang (2021) present a case study on Huangshan Mountain, focusing on the design and data governance of a disaster management system based on Big Data and IoT. This system demonstrates the stages of disaster management, from pre-disaster early warning to post-disaster recovery. The application of big data in this context shows how technology can be leveraged to improve disaster resilience in tourist areas, emphasizing the importance of early warning systems and effective recovery strategies in preserving both natural beauty and economic stability.

Similarly, another study by Wang, Liao and Zhang (2021) on Huangshan Mountain showcases a system design for environmental disaster management in smart scenic areas. This case study further elaborates on the use of big data and IoT in enhancing disaster preparedness and response in tourism sectors. The implementation of advanced technologies in disaster warning, relief and assessment illustrates the potential of big data in transforming disaster management practices, making them more efficient and responsive to the unique challenges faced by tourist destinations.

Rane and Mishra (2018) explore the application of business analytics in disaster management through the DIPPS model. This model, along with multiple field case studies, demonstrates how big data analytics and the industrial internet of things (IIoT) can lead to breakthrough business results. These success stories provide valuable insights into the effective deployment of analytics in disaster management, highlighting the potential of data-driven strategies in achieving sustainable business excellence and enhancing disaster resilience.

From leveraging cultural narratives in Indonesia to implementing technological solutions in tourist areas and adopting advanced analytics models, these success stories underscore the versatility and effectiveness of data-driven strategies in disaster management. They highlight the need for an integrated approach that combines traditional knowledge with modern technology and analytics, paving the way for comprehensive and effective disaster management solutions. These success stories not only demonstrate the potential of big data in enhancing

disaster preparedness and response but also emphasize the importance of adapting these technologies to local contexts and specific needs of communities and industries.

DISCUSSION OF THE LITERATURE REVIEW FINDINGS

Interpreting the Impact of Big Data on Disaster Resilience

The impact of big data on disaster resilience is a multifaceted phenomenon, encompassing various aspects of disaster management and response. Sarker et al. (2020) explore the potential of big data in enhancing resilience against socio-ecological vulnerability. Their study emphasizes that disaster resilience is an integrated function of adaptive, absorptive and transformative capacities, which can be significantly enhanced through big data technologies. The study highlights the importance of open-source tools, strong infrastructure, local skill development and ethical data sharing in utilizing big data effectively for disaster management. Rathnasinghe and Kulatunga (2019) discuss the potential of big data in disaster resilience, particularly in the context of Sri Lanka. Their research marks the importance of big data in predicting human behavioral patterns during disasters and managing human and physical resources in disaster-prone areas. The study underscores the role of big data in issuing early warnings, coordinating disaster management activities, and identifying effective response methods for various situations, thereby enhancing disaster resilience.

Sarker et al. (2020) in another study, delve into the potentiality of leveraging big data for disaster resilience. The research reveals that big data can play a crucial role in all stages of disaster management, ensuring the resilience capacity of social units. The study also addresses the challenges in data collection, analytics, infrastructure, and coordination, recommending the implementation of proper infrastructure and technologies for maximizing the benefits of big data in disaster resilience.

Sarker et al. (2020) further substantiate the role of big data in enhancing disaster resilience and contributing to environmental sustainability. Their study summarizes recent research on big data technologies in disaster management, highlighting how these technologies improve the speed and effectiveness of disaster information processing and systemic response. The study emphasizes the major components of effective big data use, including remote sensing imagery, social media data, crowdsourced data, geographic information systems (GIS) and mobile metadata.

The impact of big data on disaster resilience is profound and wide-ranging. Big data technologies enhance the adaptive, absorptive and transformative capacities essential for effective disaster management. They facilitate early warning systems, efficient coordination of disaster management activities, and improved decision-making. The integration of big data in disaster management not only enhances resilience but also contributes to environmental sustainability, underscoring the need for continued research and development in this field.

Integrating Geological Insights with Business Strategies

The integration of geological insights with business strategies in disaster management represents a significant advancement in the field, leveraging the potential of big data to enhance resilience and response capabilities. Khan et al. (2023) provide a comprehensive assessment of disaster management systems, focusing on flood control as a major category of natural disasters. Their study explores the integration of cutting-edge technologies such as big data analysis, cloud computing, the Internet of Things (IoT), and sensor networks in disaster management. This integration facilitates scalable and reliable infrastructure for data storage, processing, and

analysis, enhancing situational awareness and enabling prompt actions in flood-prone areas. The study underscores the importance of model-driven engineering in developing and modeling flood scenarios, aiding in preparation and response planning.

Avalon-Cullen et al. (2023) focus on the Caribbean region, particularly Jamaica, which is highly vulnerable to multiple hazards including floods and landslides. Their study reviews the current state of knowledge, data, models and tools for disaster risk reduction (DRR) planning and response. The research highlights the integration of Earth Observation (EO) data and models in enhancing national DRR frameworks. This approach serves as an analysis of the current state of DRR management and assesses future opportunities for integrating big data and geological insights into business strategies for effective disaster management. The study illustrates the potential of big data in guiding policy improvements and effective disaster management strategies, especially in Small Island Developing States (SIDS) facing multiple and compounding hazards.

The integration of geological insights with business strategies in disaster management is characterized by the innovative application of big data and advanced technologies. These technologies not only enhance the efficiency and effectiveness of disaster management systems but also pave the way for the development of smart, resilient strategies capable of withstanding and responding to various disaster scenarios. The combination of geological understanding with business acumen is crucial in developing comprehensive strategies for disaster management and mitigation.

The integration of geological insights with business strategies in disaster management, facilitated by big data, represents a significant advancement in enhancing global disaster resilience and preparedness. The development of systems and frameworks that leverage big data for monitoring, predicting and responding to geological disasters exemplifies the potential of this technology in enhancing disaster resilience. The role of big data in enhancing crisis management, particularly through advanced computing technologies and geological insights, further underscores its transformative impact in this field.

Policy Implications and Recommendations for Future Practices in Disaster Management with Big Data

The integration of big data into disaster management has significant policy implications and offers a range of recommendations for future practices. Yu, Yang and Li (2018) provide a systematic review of the role of big data in natural disaster management, highlighting its varied possibilities in visualizing, analyzing and predicting natural disasters. The study emphasizes that big data has radically changed the ways through which societies adopt natural disaster management strategies, reducing human suffering and economic losses. The paper presents findings on varied scientific and technological perspectives that impact the efficacy of big data in facilitating natural disaster management. This includes a review of major big data sources and achievements in different disaster management phases, as well as emerging technological topics associated with leveraging big data to monitor and detect natural hazards, mitigate their effects, assist in relief efforts and contribute to recovery and reconstruction processes.

Kim (2019) explores the policy implications of disaster safety management governance using data. The study highlights the increasing interest in establishing a disaster safety management system using data, emphasizing the need for a large amount of big data distribution generated in real time and its systematic management. The research underscores efforts to improve the

quality of data to increase the prevention effect of disasters through data analysis and to make a system that can respond effectively and predict the overall situation caused by disasters. The study suggests that disaster management should seek both precautionary measures and quick responses in the event of a disaster, as well as a technical approach to establishing governance and safety.

The policy implications of integrating big data into disaster management are profound. Big data offers transformative potential in enhancing the efficiency and effectiveness of disaster management strategies. Policymakers and disaster management professionals are encouraged to leverage big data for early warning systems, risk assessment and mitigation strategies. The studies recommend developing infrastructure and technologies that support the effective use of big data in disaster management. Additionally, there is a need for policies that ensure ethical data sharing, privacy protection and the development of local skills to handle and analyze big data effectively. The integration of big data into disaster management not only enhances resilience but also contributes to sustainable development and environmental sustainability.

Addressing the Challenges and Limitations Identified in Big Data Applications in Disaster Management

The application of big data in disaster management, while transformative, is not without its challenges and limitations. Akter and Wamba (2019) conducted a systematic review that reveals a fragmented landscape of research in big data and disaster management. Their study emphasizes the need for a cohesive understanding of big data's role in this field, identifying gaps and challenges that need to be addressed. The review suggests a future research agenda that includes a classification of publications, analysis of trends and the impact of published research in disaster management. This comprehensive approach is essential for better understanding and leveraging big data in disaster management.

Shah et al. (2019) discuss the rising role of big data analytics and the Internet of Things (IoT) in disaster management. They highlight the importance of these technologies in acquiring state-of-the-art assistance and improved insights for accurate and timely decision-making. The paper investigates recent studies directed towards the effective utilization of big data and IoT in disaster management. It proposes a conceptual reference model for deploying big data and IoT-based disaster management environments, addressing the challenges of integrating multiple new data sources and real-time big data processing tools. The model provides guidelines for harvesting, transmitting, managing, and analyzing disaster data from various sources to deliver updated and valuable information for disaster management.

Addressing the challenges and limitations of big data applications in disaster management requires a systematic and cohesive approach. Future research should focus on developing integrated models that combine big data analytics and IoT technologies. These models should support multiple data sources and real-time processing tools to assist decision-makers with quick and accurate results. The integration of big data in disaster management not only enhances resilience but also contributes to sustainable development and environmental sustainability. By addressing these challenges, big data can be effectively leveraged to improve disaster management practices and policies.

CONCLUSION

This study embarked on an exploratory journey to unravel the intricate role of big data in U.S. disaster mitigation and response, viewed through the dual lenses of geology and business. The

aims and objectives were meticulously crafted to dissect the evolution of big data in disaster management, its economic implications, and the theoretical frameworks guiding its application. The study successfully achieved these objectives, offering a panoramic view of the transformative impact of big data in this critical domain.

Adopting a qualitative methodology, the literature review methodically synthesized and analyzed peer-reviewed articles and studies. This approach illuminated the multifaceted role of big data in enhancing disaster resilience, streamlining response strategies and providing economic benefits through efficient disaster mitigation strategies. The review also delved into the environmental impact assessment of big data applications and presented comparative analyses of pre and post-big data disaster responses, enriched with insightful case studies.

The study underscored the effectiveness of big data in predicting natural disasters, revolutionizing disaster response mechanisms, and contributing to economic resilience. The integration of geological insights with business strategies emerged as a pivotal theme, highlighting the synergy between technological innovation and strategic management in disaster scenarios. The study also identified significant challenges and limitations in current big data applications, emphasizing the need for a cohesive and integrated approach to leverage these technologies effectively.

In conclusion, this study recommends that policymakers and disaster management professionals embrace big data as a cornerstone for developing more resilient, efficient and sustainable disaster management practices. Future research should focus on bridging the identified gaps, particularly in predictive analytics, prevention strategies, and real-time disaster recovery. The integration of big data, with its vast potential to transform disaster management, stands as a beacon of hope and a testament to human ingenuity in the face of adversity. As we venture into an era where data is as crucial as the strategies it informs, this study paves the way for a more data-driven, responsive, and resilient approach to disaster management.

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