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BIG DATA AND ARTIFICIAL INTELLIGENCE IN LOCAL GOVERNMENT DISASTER RISK MANAGEMENT: TOWARD RESPONSIVE AND ADAPTIVE GOVERNANCE

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Abstract

This study aims to analyze the integration of big data and artificial intelligence in local government disaster risk management as a basis for building responsive and adaptive governance. The study focuses on four main disaster management functions: mitigation, early warning, emergency response, and post-disaster aid distribution. This research uses a qualitative method with an exploratory-descriptive approach and conceptual model development. Data were collected from secondary and documentary sources, including recent peer-reviewed journal articles, policy documents, institutional reports, disaster management guidelines, and regulatory materials related to big data, artificial intelligence, disaster risk reduction, and local government management. The data were analyzed through thematic analysis by classifying key findings into data integration, AI-supported risk intelligence, adaptive decision-making, emergency coordination, aid distribution, institutional readiness, ethical governance, and public accountability. The findings show that big data can strengthen disaster mitigation and early warning by integrating geospatial, meteorological, demographic, infrastructure, social media, and community-level data. AI supports emergency response and recovery by enabling predictive analysis, damage estimation, urgent-needs classification, misinformation detection, evacuation support, and assistance prioritization. The study contributes by proposing an integrated big data and AI-based local government disaster risk management model consisting of data integration, AI-supported risk intelligence, adaptive decision-making, coordinated emergency response, and accountable post-disaster recovery. This model emphasizes that technology must be supported by institutional capacity, human oversight, data governance, community participation, and ethical safeguards.

Keywords: artificial intelligence; big data; disaster risk management; local government; responsive governance.

1. INTRODUCTION

Disaster risk management has become one of the most strategic areas of local government responsibility in the era of digital governance. Local governments are often the first institutional actors required to identify risks, activate early warnings, coordinate emergency response, distribute assistance, and support post-disaster recovery. These responsibilities are increasingly complex because disasters are no longer understood only as natural events, but as multidimensional crises involving environmental vulnerability, urban expansion, infrastructure fragility, social inequality, public communication, and administrative capacity. In this context, traditional disaster management systems that rely heavily on manual reporting, fragmented databases, and reactive bureaucratic procedures are no longer sufficient. Local governments need a management system that can process large volumes of data, detect risk signals more rapidly, support real-time coordination, and guide policy decisions based on evidence. Big data and artificial intelligence offer a significant opportunity to strengthen this capacity by transforming disaster governance from a reactive model into a more anticipatory, responsive, and adaptive model [1], [2].

The use of big data in disaster risk management enables local governments to collect and analyze various forms of information, including satellite imagery, geographic information systems, sensor data, meteorological records, population data, infrastructure data, social media content, mobility patterns, public complaints, and humanitarian logistics information. These data sources can support mitigation planning, risk mapping, early warning, emergency prioritization, and post-disaster aid distribution. Artificial intelligence strengthens this process by enabling predictive analytics, pattern recognition, automated classification, image interpretation, natural language processing, and decision-support modelling. Recent studies show that AI can be used across disaster phases, including mitigation, preparedness, response, and recovery [3], [4]. AI-based systems can help identify disaster-prone areas, estimate damage, classify urgent needs, optimize evacuation routes, detect misinformation, and improve the targeting of relief assistance. Big data analytics also plays an important role in humanitarian and disaster operations by improving visibility, coordination, and operational responsiveness [5]. These developments indicate that disaster management is gradually moving toward data-driven governance, where public decisions are supported by integrated information systems and intelligent analytical tools.

Despite this potential, the adoption of big data and AI in local government disaster management faces several institutional and ethical challenges. Many local governments still experience weak data integration, limited technical capacity, sectoral ego among agencies, low interoperability, uneven digital infrastructure, and limited human-resource readiness. Disaster-related data are frequently distributed across different institutions, including disaster management agencies, public works departments, social affairs offices, health agencies, meteorological institutions, village governments, and civil society organizations. Without strong data governance, AI systems may produce inaccurate predictions, biased classifications, or inappropriate policy recommendations. Ethical risks also emerge when disaster data involve vulnerable communities, personal information, location tracking, and automated prioritization of assistance. Explainable AI is increasingly relevant in this context because disaster-related decisions may affect evacuation, eligibility for aid, service prioritization, and public safety [2]. AI and big data can improve disaster governance, but their legitimacy depends on transparency, accountability, fairness, privacy protection, and the ability of citizens to question government decisions that are supported by algorithmic systems [1], [6].

Several recent studies have examined the intersection between AI, big data, and disaster risk management. Ghaffarian et al. [2] emphasize the importance of explainable AI in disaster risk management, especially because AI-based disaster decisions require transparency and interpretability. Chun et al. [1] discuss the legal and interdisciplinary dimensions of AI and big data in disaster risk reduction, highlighting the need for safety, accountability, fairness, and contestability. Bari et al. [3] show that AI can support disaster risk and emergency health management through prediction, preparedness, response, and recovery. Khan et al. [7] provide a systematic review of disaster management systems and identify the importance of integrated technologies, data architecture, and intelligent decision support. Albahri et al. [8] examine trustworthy AI applications in natural disasters and stress the need for reliability, explainability, and ethical safeguards. Fan et al. [9] propose the concept of a disaster city digital twin that integrates artificial and human intelligence for disaster management. Lagap and Ghaffarian [10] further develop digital post-disaster risk management twinning as a framework for improving response and recovery through real-time virtual representation. These studies show that AI and big data are increasingly positioned as critical instruments for improving disaster intelligence, yet they also reveal that technological adoption must be connected to governance capacity.

Other related works focus on social media analytics, humanitarian logistics, local risk information, and public participation in disaster governance. Erokhin and Komendantova [11] demonstrate that social media data can support disaster risk management by capturing real-time public sentiment, urgent needs, and community reactions. Ogie et al. [12] show that social media use in disaster recovery provides opportunities for communication, coordination, and community engagement, while also raising problems of misinformation and data reliability. Guo et al. [13] use social media data to evaluate urban flood impacts in data-scarce cities, indicating that citizen-generated data can complement official datasets. Nasution et al. [14] examine flood vulnerability in Jakarta through hybrid fuzzy spatial clustering and news media analysis, showing the relevance of combining spatial and textual data for local disaster assessment. Kondraganti et al. [5] systematically review big data analytics in humanitarian and disaster operations and show that data analytics can improve coordination, preparedness, and operational effectiveness. Dubey et al. [15] also demonstrate that AI-driven big data analytics can enhance agility and resilience in humanitarian supply chains. Kankanamge et al. [16] add an important citizen perspective by showing that public perceptions influence the acceptance of AI-driven disaster management. These studies provide strong evidence that disaster governance cannot rely only on technical systems; it must also address institutional trust, public communication, community participation, and ethical data use.

The existing literature has produced important insights into AI-based prediction, big data analytics, social media data, humanitarian logistics, digital twins, and explainable AI in disaster contexts. Yet, a gap remains in explaining how these technologies can be integrated into **local government management** as a coherent governance model for mitigation, early detection, emergency response, and post-disaster aid distribution. Many studies discuss AI and big data as technical tools, while fewer studies connect them directly with the managerial functions of local government, including inter-agency coordination, bureaucratic workflow, public accountability, community-level responsiveness, and adaptive decision-making. This study addresses that gap by examining the use of big data and artificial intelligence in local government disaster risk management and by proposing an integrated model of responsive and adaptive governance. The study aims to analyze how big data and AI can support disaster mitigation, early warning, emergency response, and post-disaster assistance, while ensuring that local government decision-making remains accountable, ethical, inclusive, and oriented toward public safety.

2. RESEARCH METHODS

This study employs a qualitative research design with an exploratory-descriptive approach. The qualitative method is considered appropriate because the study does not aim to test statistical relationships or measure the effectiveness of a specific AI algorithm quantitatively. Instead, it seeks to understand how artificial intelligence can transform government management, improve public-service processes, support administrative decision-making, and increase bureaucratic efficiency within the broader framework of digital governance. The study is also supported by a conceptual model-building approach, since its main novelty is to formulate an adaptive AI-based government management model that integrates service quality, organizational adaptation, ethical governance, human oversight, and public accountability. In this sense, AI is not treated as a technical algorithm to be trained or tested, but as a governance instrument that must be analyzed from managerial, institutional, and ethical perspectives [1], [17], [18].

The case study of this research focuses on AI-based public service management within government institutions in the digital governance era, particularly in the context of public-service delivery, administrative decision-making, and bureaucratic workflow transformation. The study places government institutions as the main unit of analysis, with attention to how AI can be applied in service portals, digital complaint systems, automated document processing, citizen-facing chatbots, decision-support systems, and data-driven policy formulation. The case study is designed as an institutional and managerial case rather than a single-application evaluation. This means that the research examines AI adoption as part of government management transformation, including changes in organizational structure, data governance, human-resource capacity, service standards, accountability mechanisms, and ethical control. This approach is relevant because previous studies show that successful AI implementation in the public sector depends not only on technological readiness, but also on institutional capacity, public trust, explainability, and responsible governance [3], [12], [19].

The data used in this study are collected from secondary and documentary sources, consisting of peer-reviewed journal articles published within the last five years, official government documents related to digital governance and public-service transformation, policy reports, regulatory documents, and institutional publications concerning AI governance in the public sector. The literature sources are selected from reputable academic databases and journals, especially those discussing artificial intelligence in public administration, digital government, public-service innovation, algorithmic accountability, explainable AI, and ethical governance. Data collection is conducted through systematic document identification, relevance screening, thematic classification, and content analysis. The collected data are then analyzed using qualitative thematic analysis, focusing on several key themes: AI utilization in public services, AI-supported decision-making, bureaucratic efficiency, organizational readiness, ethical risks, accountability, transparency, and public value creation. The results of this analysis serve as the basis for constructing an adaptive AI-based government management model that is both innovation-oriented and normatively accountable.

3. RESULTS AND DISCUSSION

a. Big Data-Driven Disaster Mitigation and Early Warning in Local Government

The thematic analysis shows that big data can strengthen disaster mitigation by improving the ability of local governments to identify risk patterns before a disaster occurs. In conventional disaster management, local governments often depend on historical records, field reports, and sectoral data submitted by different agencies. These sources remain important, but they are frequently fragmented, delayed, and unable to capture dynamic changes in hazard exposure, population movement, land-use change, infrastructure vulnerability, and community preparedness. Big data provides a more comprehensive evidence base by integrating geospatial data, meteorological information, demographic records, infrastructure data, disaster-prone area maps, public complaints, social media data, and local community reports. This integration enables local governments to build more accurate risk profiles and identify priority areas for mitigation programs.

The findings indicate that big data-based mitigation is most useful when local governments are able to connect risk information with planning and budgeting processes. Risk maps, vulnerability indicators, and predictive data should not only be used for technical reports, but also for determining development priorities, infrastructure investment, spatial planning, community preparedness programs, and contingency planning. This finding is consistent with Khan et al. [7], who emphasize that disaster management systems require integrated data architecture and intelligent decision support. It also supports Ghaffarian et al. [2], who argue that AI and data-driven systems can strengthen disaster risk management when their outputs are interpretable and institutionally usable. In this study, big data is not understood only as a collection of large datasets, but as a governance resource that helps local governments transform scattered information into actionable policy knowledge.

Big data also contributes to early warning by allowing local governments to detect abnormal patterns and potential risk signals more quickly. For example, rainfall data, river-level sensors, satellite imagery, public complaints, and social media posts can be analyzed to identify the possibility of floods, landslides, droughts, or infrastructure failure. AI can strengthen this process through pattern recognition, anomaly detection, and predictive analytics. Wanckel's argument on big data algorithm systems in early crisis detection is relevant here because local governments need preventive capacity rather than purely reactive response mechanisms [9]. Sahana et al. [17] also show that early warning systems and emergency preparedness are essential for reducing disaster losses. The finding of this study confirms that early warning should be treated as a managerial system, not merely as a technological alert. Warning information must be connected to command structures, communication channels, evacuation procedures, and community-level preparedness.

The discussion also reveals that early warning based on big data and AI requires strong data governance. If the data are incomplete, outdated, or inconsistent, AI-based predictions may produce inaccurate risk signals. This can lead to false alarms, delayed response, or misallocation of emergency resources. In disaster contexts, inaccurate data can directly affect public safety. For this reason, local governments must establish data standards, validation mechanisms, interoperability protocols, and clear institutional responsibilities. Liu et al. [19] show that governmental data governance affects urban risk management, including fire-risk governance. This supports the finding that big data-based disaster mitigation depends not only on technological capacity, but also on the quality of public data management.

b. AI-Supported Emergency Response and Post-Disaster Aid Distribution

The second finding shows that artificial intelligence can improve emergency response by supporting rapid situation analysis, resource prioritization, evacuation support, and coordination among agencies. During emergencies, local governments must make decisions under time pressure, uncertainty, and limited information. AI can assist by processing real-time data from disaster reports, satellite imagery, drones, call centers, social media, emergency hotlines, and field officers. These data can be used to estimate affected areas, classify urgent needs, identify damaged infrastructure, prioritize evacuation zones, and support operational decisions. Bari et al. [3] explain that AI has potential in emergency and disaster health management because it can support prediction, preparedness, response, and recovery. This study extends that argument by positioning AI as part of local government emergency management, especially in connecting data analysis with administrative coordination.

AI can also strengthen communication during emergency response. Natural language processing can be used to classify citizen reports, detect urgent messages, identify misinformation, and analyze public sentiment during disasters. Social media data are especially relevant because citizens often share information faster than formal bureaucratic reporting channels. Erokhin and Komendantova [11] show that social media data can support disaster risk management and research by capturing real-time public reactions and information flows. Ogie et al. [12] also emphasize that social media can support disaster recovery through communication and community engagement, although misinformation and data reliability remain major challenges. The finding of this study confirms that local governments should not ignore citizen-generated data, but they must verify it through official channels before using it as a basis for emergency decisions.

In the post-disaster phase, big data and AI can improve the accuracy and fairness of aid distribution. Local governments often face problems in distributing assistance, such as overlapping beneficiary lists, delayed verification, unequal access, inaccurate damage assessment, and limited coordination between agencies. Big data can help integrate population records, social assistance databases, village-level data, geospatial damage maps, household vulnerability data, and field assessment reports. AI can support this process by classifying damage levels, estimating priority needs, identifying vulnerable groups, and detecting potential duplication in beneficiary data. Dubey et al. [15] show that AI-driven big data analytics can improve agility and resilience in humanitarian supply chains. Kondraganti et al. [5] also highlight the role of big data analytics in improving humanitarian and disaster operations. These studies support the finding that AI and big data can make post-disaster aid distribution more targeted, timely, and accountable.

Yet, AI-supported aid distribution must be managed carefully because it directly affects vulnerable communities. If the algorithm uses biased, incomplete, or outdated data, eligible victims may be excluded from assistance. Automated classification may also fail to capture local realities, informal settlements, undocumented residents, persons with disabilities, elderly citizens, or households whose vulnerability is not visible in administrative databases. Chun et al. [1] emphasize that AI and big data in disaster risk reduction require legal and interdisciplinary safeguards, including fairness, safety, accountability, and contestability. Ghaffarian et al. [2] also stress the importance of explainable AI in disaster risk management. The finding of this study confirms that AI may support aid prioritization, but final decisions must remain under the responsibility of authorized public officials. Human verification, local knowledge, and complaint mechanisms are essential to prevent algorithmic exclusion.

c. Toward a Responsive and Adaptive Local Government Disaster Risk Management Model

The main analytical result of this study is the formulation of an integrated model of big data and AI-based local government disaster risk management. The model consists of five interrelated components: data integration, AI-supported risk intelligence, adaptive decision-making, coordinated emergency response, and accountable post-disaster recovery**.** Data integration refers to the ability of local governments to connect multiple data sources across agencies, including disaster management agencies, public works offices, social affairs departments, health agencies, village governments, meteorological institutions, and community organizations. AI-supported risk intelligence refers to the use of predictive analytics, spatial analysis, image recognition, and natural language processing to convert disaster data into policy-relevant knowledge. Adaptive decision-making refers to the ability of local governments to revise response strategies based on real-time evidence. Coordinated emergency response emphasizes inter-agency collaboration and rapid operational mobilization. Accountable post-disaster recovery ensures that assistance, rehabilitation, and reconstruction remain transparent, inclusive, and subject to public scrutiny.

This model contributes to previous studies by connecting big data and AI with the managerial functions of local government. Existing literature has discussed AI-based disaster prediction, digital twins, social media analytics, humanitarian logistics, and trustworthy AI [2], [5], [8], [9], [10]. This study extends those discussions by emphasizing that technological tools must be embedded in local government management processes. Digital twins, for instance, can provide advanced simulation and real-time representation of disaster conditions, as explained by Fan et al. [9] and Lagap and Ghaffarian [10]. Yet, such technologies will have limited impact if local governments lack coordination mechanisms, clear authority, trained personnel, and operational procedures. The proposed model places technology within the broader governance cycle of mitigation, preparedness, response, and recovery.

The findings also show that responsive governance requires speed, while adaptive governance requires learning capacity. A responsive local government is able to detect risks, communicate warnings, mobilize resources, and respond quickly to emergency needs. An adaptive local government is able to learn from disaster events, update risk maps, revise contingency plans, improve data systems, and redesign institutional procedures after evaluation. This distinction is important because rapid response alone does not guarantee better disaster governance. Local governments must also develop institutional memory and analytical capacity so that each disaster experience becomes a source of policy learning. Tseng and Stojadinović [21] emphasize the importance of socio-technical capability in disaster resilience assessment. This supports the argument that disaster resilience depends on the interaction between technology, institutions, human capacity, and community participation.

The discussion further indicates that public participation remains essential in AI and big data-based disaster governance. Big data may reveal patterns, but it cannot fully capture lived experience, local knowledge, social vulnerability, and community trust. MacAfee et al. [20] show that local knowledge is important for landslide disaster risk reduction, particularly in vulnerable urban settlements. Kankanamge et al. [16] also demonstrate that public perception influences the acceptance of AI-driven disaster management. These studies support the finding that local governments should combine data-driven intelligence with community-based knowledge. Citizen reports, village-level information, local volunteers, and community organizations can improve the accuracy of risk identification and emergency response.

The model proposed in this study also requires ethical and accountable governance. Disaster-related big data may include sensitive information, such as location data, health conditions, poverty status, household vulnerability, mobility patterns, and social assistance records. The use of these data must be regulated through privacy protection, transparency, explainability, audit mechanisms, and accessible grievance channels. De Bruijn et al. [6] explain that explainable AI is necessary to address the risks of opaque algorithmic decision-making. Zuiderwijk et al. [22] also argue that AI in public governance raises institutional, ethical, and societal implications. In the context of local disaster management, these concerns are highly relevant because AI-supported decisions may determine who receives help first, which area is prioritized, and how public resources are distributed.

Based on the overall analysis, this study finds that big data and AI can transform local government disaster risk management when they are integrated into a coherent governance system. Big data improves the evidence base for mitigation and planning. AI strengthens early warning, emergency response, and post-disaster aid targeting. Local government management connects these technologies with institutional authority, coordination, and public accountability. The proposed model shows that disaster governance in the digital era should not depend solely on technological sophistication. It must combine data intelligence, institutional readiness, human oversight, community participation, and ethical safeguards. This is the main requirement for building responsive and adaptive local government disaster risk management.

4. CONCLUSION

This study finds that big data and artificial intelligence can transform local government disaster risk management from a reactive administrative system into a more anticipatory, responsive, and adaptive governance model. Big data strengthens disaster mitigation and early warning by integrating diverse information sources, including geospatial data, meteorological records, demographic data, infrastructure conditions, disaster-prone area maps, public complaints, social media content, and community-level reports. These data sources enable local governments to identify risk patterns, map vulnerability, determine priority areas, and prepare more evidence-based mitigation strategies. AI further enhances this process through predictive analytics, anomaly detection, image recognition, natural language processing, and automated classification of disaster-related information.

The findings also show that AI can improve emergency response and post-disaster aid distribution when it is connected to local government coordination mechanisms. AI-supported systems can assist in estimating affected areas, classifying urgent needs, detecting misinformation, supporting evacuation decisions, identifying vulnerable groups, and prioritizing assistance. Big data can also reduce duplication and inaccuracy in aid distribution by integrating population records, social assistance databases, village-level information, geospatial damage maps, and field assessment reports. These findings indicate that AI and big data are not merely technical tools, but strategic instruments for strengthening local government capacity in managing disaster risks and protecting affected communities.

The novelty of this study lies in the formulation of an integrated big data and AI-based local government disaster risk management model. The model consists of five interrelated components: data integration, AI-supported risk intelligence, adaptive decision-making, coordinated emergency response, and accountable post-disaster recovery. This model differs from previous studies that often examine AI-based disaster prediction, digital twins, social media analytics, or humanitarian logistics separately. This study connects those technological dimensions with the managerial functions of local government, particularly in mitigation planning, early detection, emergency coordination, and post-disaster assistance.

The results imply that the success of AI and big data adoption in disaster governance depends on more than technological sophistication. Local governments need strong data governance, institutional interoperability, clear command structures, trained human resources, reliable communication systems, and mechanisms for public accountability. The study also emphasizes that AI-supported disaster decisions must remain under human supervision because disaster governance involves public safety, vulnerable communities, sensitive personal data, and urgent resource allocation. Ethical safeguards such as privacy protection, transparency, explainability, audit mechanisms, and complaint channels are essential to prevent algorithmic bias, data misuse, and exclusion of disaster-affected citizens.

This study has limitations because it uses a qualitative and documentary-based approach. The proposed model has not yet been tested through fieldwork, institutional observation, interviews with disaster management officials, or direct evaluation of AI-based disaster systems. Future research should examine the empirical application of this model in specific disaster contexts, such as floods, earthquakes, landslides, droughts, volcanic eruptions, or post-disaster social assistance programs. Further studies may use mixed methods by combining interviews, surveys, geospatial analysis, disaster-response performance indicators, and community satisfaction data. Comparative studies across local governments would also be valuable to explain how institutional capacity, digital infrastructure, administrative culture, community participation, and legal frameworks influence the effectiveness of big data and AI-based disaster risk management.

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