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A Smart Disaster Governance Model for Local Governments: Integrating the Internet of Things, Big Data, and Public Participation in Disaster Management

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Abstract:
This study examines the development of a smart disaster governance model for local governments in Indonesia by integrating the Internet of Things, big data, and public participation in disaster management. The study is based on the argument that disaster governance can no longer rely solely on conventional administrative procedures, sectoral reporting, and reactive emergency response. Local governments need a governance framework that enables real-time risk monitoring, interoperable disaster data, data-driven decision-making, cross-sectoral coordination, and citizen engagement. Using a qualitative case study approach, this research analyzes institutional readiness, digital disaster infrastructure, IoT-based monitoring, big data utilization, public reporting mechanisms, and participatory coordination in disaster-prone local government contexts. Data were collected through in-depth interviews, field observations, and document analysis involving regional disaster management agencies, communication and informatics offices, planning agencies, public works offices, health and social affairs offices, command center operators, disaster volunteers, community leaders, and residents in disaster-prone areas. The findings show that digital tools have begun to support disaster management, but their effectiveness remains limited by fragmented data, weak interoperability, unclear institutional responsibilities, and insufficient integration of citizen-generated information. This study proposes a smart disaster governance model consisting of six components: real-time risk monitoring, integrated disaster data platform, big data-based decision support, participatory public reporting, cross-sectoral command coordination, and accountability-based evaluation. The novelty of this study lies in integrating technological intelligence, institutional intelligence, and social intelligence into one local government disaster governance framework.

Keywords: smart disaster governance; Internet of Things; big data; public participation; local government; disaster management; Indonesia

1. Introduction

Disaster governance in Indonesia faces increasingly complex challenges due to the interaction between high disaster exposure, rapid urbanization, climate variability, environmental degradation, population concentration, and uneven local government capacity. As an archipelagic country located in the Pacific Ring of Fire and affected by hydrometeorological hazards, Indonesia repeatedly experiences floods, landslides, earthquakes, tsunamis, volcanic eruptions, forest and land fires, droughts, and extreme weather events. These hazards require local governments to make rapid, accurate, and coordinated decisions, particularly in risk monitoring, early warning, evacuation, logistics distribution, public communication, and recovery planning. In this context, disaster management can no longer depend only on conventional administrative reporting and sectoral coordination. It requires a smart governance approach that integrates digital technology, real-time data, institutional collaboration, and public participation (Shahat et al., 2020; Shah et al., 2019; Kankanamge et al., 2020).

In the Indonesian local government context, the need for smart disaster governance is closely related to the limitations of fragmented disaster information systems. Regional disaster management agencies, meteorological agencies, public works offices, health offices, social affairs offices, communication and informatics offices, village governments, and community volunteers often collect and manage different data sets. Hazard data, population data, evacuation data, infrastructure data, logistics data, community reports, and post-disaster damage data are not always connected in a real-time and interoperable system. This fragmentation can delay decision-making and weaken disaster response, particularly when disasters affect densely populated or vulnerable areas. Studies on Indonesian disaster governance show that local disaster management is frequently constrained by coordination gaps, uneven institutional capacity, and limited integration between formal government systems and community-based information (Kusumasari & Alam, 2021; Lassa et al., 2022; MacAfee et al., 2024; Syamsidik et al., 2021).

The development of smart city initiatives in several Indonesian regions provides an important opportunity for strengthening disaster governance. Smart city programs have encouraged local governments to adopt digital platforms, public complaint applications, command centers, geospatial dashboards, CCTV-based monitoring, weather sensors, and integrated emergency services. These instruments can support disaster management when they are connected to hazard monitoring, early warning systems, evacuation planning, public reporting, and emergency coordination. Research on smart city governance in Indonesia indicates that digital innovation can improve service delivery, urban monitoring, and citizen engagement, but its effectiveness depends on institutional readiness, data governance, interoperability, and the ability of citizens to access and use digital services (Achmad et al., 2018; Herdiyanti et al., 2019; Pratama, 2021; Herdiyanti et al., 2021). In disaster contexts, these challenges become more urgent because digital systems must work under conditions of uncertainty, infrastructure disruption, and time pressure.

Previous studies have discussed the role of digital technology in disaster management from different perspectives. Shah et al. (2019) reviewed the integration of big data analytics and Internet of Things in disaster management and showed that both technologies can improve early warning, risk assessment, emergency response, and decision support. Shahat et al. (2020) conceptualized smart disaster governance by emphasizing the role of IoT in real-time disaster monitoring, data acquisition, and coordination. Gaire et al. (2018) explained that IoT, cloud computing, and social computing can support situation-aware disaster management by collecting and processing real-time information from sensors and citizen-generated data. Mouradian et al. (2018) demonstrated that distributed IoT gateway architecture can support large-scale disaster management when conventional communication infrastructure is disrupted. Kankanamge et al. (2020) showed that social media analytics can help determine disaster severity and improve situational awareness during floods.

In Indonesia, research has also shown that digital systems are increasingly relevant for disaster risk reduction. Studies on early warning systems, flood monitoring, landslide risk reduction, smart city platforms, and community-based disaster information indicate that digital technology can help local governments detect hazards, disseminate warnings, coordinate response, and collect public reports. For example, studies on flood early warning systems using IoT-based sensors in Indonesian urban areas show that real-time water-level monitoring can improve preparedness and local response. Research on landslide disaster risk reduction in Manado demonstrates that local knowledge and data-informed approaches can strengthen urban informal settlement resilience (MacAfee et al., 2024). Studies on tsunami preparedness in Aceh also show that technology-based warning systems must be supported by institutional learning, community preparedness, and public trust (Syamsidik et al., 2021). These studies indicate that digital disaster management in Indonesia cannot be separated from local institutional and social contexts.

Public participation is another essential element of smart disaster governance. Disaster risk information is not produced only by sensors, satellites, or formal government databases. Citizens also produce valuable information through local knowledge, community reports, social media posts, neighborhood networks, and direct experience of hazards. In Indonesian disaster-prone communities, residents often identify early signs of floods, landslides, volcanic activity, coastal hazards, or infrastructure failure before formal systems respond. When citizen-generated information is integrated into local government platforms, it can strengthen situational awareness and improve the accuracy of disaster response. Studies on participatory disaster governance emphasize that citizen involvement improves preparedness, legitimacy, trust, and accountability, especially when communities are treated not only as recipients of warning information but also as co-producers of disaster knowledge (Wolff & Muñoz, 2021; Hadlos et al., 2022; Firdaus et al., 2023; Paudel et al., 2024).

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Nevertheless, the use of IoT, big data, and public participation in disaster governance also creates new challenges. Digital disaster systems may reproduce exclusion if they are designed without considering digital literacy, internet access, disability inclusion, data privacy, and unequal technological infrastructure. Big data may improve decision-making, but it may also create problems related to data quality, algorithmic bias, interoperability, institutional accountability, and cybersecurity. IoT systems can strengthen real-time monitoring, but they require maintenance, data standards, reliable connectivity, and institutional capacity to interpret information. Citizen participation can enrich disaster information, but it requires verification mechanisms so that public reports can be used without producing misinformation or panic. Recent studies on digital disaster governance show that smart systems must be supported by data governance, ethical standards, institutional coordination, and inclusive participation (Chun, 2025; Psomakelis et al., 2016; Simmhan et al., 2018; Wolff & Muñoz, 2021).

Existing literature has provided important insights into IoT-based disaster monitoring, big data analytics, social media analytics, smart city platforms, and participatory disaster governance. However, most studies discuss these dimensions separately. Research on IoT often focuses on technical sensor architecture and early warning systems. Big data studies tend to emphasize analytics, prediction, and decision support. Public participation studies focus on community engagement, local knowledge, and citizen reporting. In the Indonesian local government context, limited studies have integrated these dimensions into a single governance framework that connects technology, data, institutions, and citizens. This gap is important because a local government may have digital applications, command centers, sensors, and public reporting channels, but disaster governance will remain fragmented if these instruments are not connected to planning, coordination, response, and accountability mechanisms.

This study addresses that gap by proposing a smart disaster governance model for local governments in Indonesia. The novelty of this study lies in integrating IoT-based monitoring, big data analytics, and public participation within one disaster governance framework. Unlike studies that focus only on technological innovation or community participation separately, this study positions smart disaster governance as a hybrid model that combines real-time digital intelligence, institutional coordination, and citizen-based knowledge. Accordingly, this study aims to analyze how local governments in Indonesia can develop smart disaster governance by integrating digital infrastructure, interoperable data systems, cross-sectoral coordination, and participatory mechanisms in disaster management. The study also seeks to formulate a governance model that enables local governments to move from reactive disaster administration toward anticipatory, data-driven, inclusive, and collaborative disaster risk management.

2. Methodology

This study employed a **qualitative research method** with a **case study approach**. The qualitative method was selected because the study aims to understand how local governments in Indonesia can develop a smart disaster governance model by integrating the Internet of Things, big data, and public participation in disaster management. The focus of this research is not to design a technical algorithm, test sensor accuracy, or measure system performance statistically. Instead, it examines governance processes, institutional readiness, data management practices, technological integration, inter-agency coordination, and citizen participation in the disaster management cycle.

The case study approach was used because smart disaster governance is highly contextual and depends on local disaster risk characteristics, digital infrastructure, institutional capacity, data interoperability, public communication systems, and community participation. The case in this study focuses on local governments in disaster-prone areas of Indonesia that have begun to adopt digital platforms, command centers, early warning systems, disaster information dashboards, public complaint applications, geospatial data, or community reporting mechanisms. The main unit of analysis is the local government disaster governance system, particularly how digital technologies and citizen-generated information are used to support mitigation, preparedness, emergency response, recovery, and accountability.

The research data were collected from both **primary and secondary sources**. Primary data were obtained through in-depth interviews with key informants, including officials from regional disaster management agencies, communication and informatics offices, regional development planning agencies,

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public works offices, health offices, social affairs offices, village or sub-district governments, command center operators, disaster volunteers, community leaders, and residents living in disaster-prone areas. These interviews were designed to explore institutional readiness, the use of digital technology in disaster management, data-sharing mechanisms, coordination among agencies, public participation channels, and challenges in integrating IoT, big data, and citizen reporting into local disaster governance.

Field observations were also conducted in selected disaster management settings, such as local disaster management offices, command centers, emergency operation centers, early warning facilities, evacuation points, flood monitoring posts, community reporting centers, and disaster-prone neighborhoods. The observations focused on how digital tools are used in practice, how disaster information is collected and processed, how warnings are communicated to citizens, how public reports are received and verified, and how coordination is carried out among government institutions and community actors. These observations were important to understand whether digital disaster systems function as integrated governance instruments or remain isolated technological tools.

Secondary data were collected through document analysis. The documents examined included regional disaster management plans, disaster risk assessment documents, contingency plans, smart city master plans, local e-government or digital transformation policies, command center reports, disaster information system documents, standard operating procedures for early warning and emergency response, public complaint records, social media reports, local regulations, and official disaster management reports. These documents were analyzed to assess whether IoT-based monitoring, big data systems, and public participation mechanisms had been formally integrated into local disaster governance.

Informants were selected using a **purposive sampling technique**. This technique was considered appropriate because the study required information from actors who have direct authority, technical knowledge, or practical experience in disaster management, digital governance, data management, and public participation. Informants were selected based on their involvement in disaster planning, operation of digital platforms, management of disaster data, coordination of emergency response, or participation in community-based disaster activities. Snowball sampling was also used when necessary to identify additional informants, especially disaster volunteers, community-based reporting actors, local technology operators, and residents who had experience using or responding to digital disaster information systems.

Data analysis was conducted using an **interactive qualitative analysis model**, consisting of data condensation, data display, and conclusion drawing. Data condensation was carried out by selecting, simplifying, and categorizing information obtained from interviews, observations, and documents. The data were then organized into thematic categories, including digital disaster infrastructure, IoT-based monitoring, big data utilization, data interoperability, public reporting channels, citizen participation, inter-agency coordination, decision-making processes, and accountability mechanisms. Data display was conducted through thematic matrices, governance mapping, and narrative interpretation to identify patterns, gaps, and relationships among technological systems, institutional actors, and participatory mechanisms.

The formulation of the smart disaster governance model was conducted through conceptual reconstruction. The empirical findings were connected with concepts of smart governance, digital government, disaster risk management, data-driven decision-making, and participatory governance. The model was developed by identifying the main components required for smart disaster governance at the local government level, including real-time risk monitoring, integrated data platforms, cross-sectoral coordination, citizen-generated reporting, participatory verification, digital early warning communication, and accountability-based evaluation. This analytical process enabled the study to formulate a governance model that combines technological intelligence, institutional intelligence, and social intelligence.

The study did not apply a specific computational algorithm such as machine learning, predictive analytics, or sensor-based simulation. Big data in this research was analyzed as a governance concept and institutional practice, referring to the use of large, diverse, real-time, and multi-source data to support disaster management decisions. Similarly, IoT was examined as part of the local government's disaster monitoring and early warning ecosystem, rather than as a technical engineering object. This distinction is important because the study focuses on governance design, not software development or hardware performance testing.

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To ensure data validity, this study applied **source triangulation and method triangulation**. Source triangulation was conducted by comparing information from government officials, technology operators, disaster volunteers, community representatives, and residents in disaster-prone areas. Method triangulation was carried out by comparing interview findings, field observations, and institutional documents. This process was used to reduce institutional bias and strengthen the credibility of the findings. Ethical considerations were maintained by ensuring voluntary participation, protecting informants' identities when necessary, and respecting the privacy of citizen-generated disaster reports, especially when they contained personal, location-based, or emergency-related information.

3. Results and Discussions

1) Digital Fragmentation and the Need for Integrated Disaster Data Governance

The findings indicate that the development of digital disaster management at the local government level in Indonesia has not always been accompanied by integrated disaster data governance. Several local governments have begun to use digital platforms, command centers, public complaint applications, early warning devices, CCTV monitoring, geospatial dashboards, and social media channels to support disaster management. These instruments show that digital transformation has entered local disaster governance. However, the main problem lies in the fragmentation of data, systems, and institutional responsibilities. Disaster-related data are often managed separately by regional disaster management agencies, communication and informatics offices, public works agencies, health offices, social affairs offices, village governments, meteorological institutions, and community-based volunteers.

This fragmentation affects the ability of local governments to build a common operational picture during disaster events. Hazard data, rainfall data, river water levels, landslide-prone zones, evacuation routes, shelter capacity, population data, vulnerable group data, logistics availability, infrastructure damage, and citizen reports are not always connected in a single interoperable system. As a result, each institution may have partial information, while decision-makers do not always receive integrated and real-time data. This finding supports Shah et al. (2019), who argue that disaster management requires the ability to process large-scale, heterogeneous, and time-sensitive data from multiple sources. It also confirms Shahat et al. (2020), who emphasize that smart disaster governance requires the integration of technology, data, and governance processes rather than the mere presence of digital devices.

The findings show that IoT-based monitoring has strong potential to improve disaster risk detection, particularly for floods, landslides, volcanic activity, extreme weather, and infrastructure failure. Sensors for water levels, rainfall intensity, soil movement, air quality, river discharge, or slope instability can provide real-time information that supports early warning and emergency preparedness. In disaster-prone local governments, such data can help agencies determine when to issue warnings, activate evacuation procedures, deploy volunteers, and prepare logistics. This finding is consistent with Gaire et al. (2018), who explain that IoT, cloud computing, and social computing can strengthen situation-aware disaster management. Mouradian et al. (2018) also show that IoT gateway architecture can support disaster management when communication and data flow must remain functional under emergency conditions.

However, the findings also reveal that IoT implementation faces governance challenges. Sensors and monitoring devices require maintenance, calibration, connectivity, budget support, standard operating procedures, and institutional responsibility. Some digital devices are installed as project outputs, but they are not always integrated into routine disaster decision-making. In some cases, data from sensors are available but not systematically analyzed, shared, or transformed into actionable warnings. This shows that smart disaster governance cannot be reduced to technology procurement. Digital infrastructure must be embedded in institutional workflows, budget planning, operational protocols, and accountability mechanisms.

Big data utilization also remains limited. Local governments collect various forms of disaster-related data, including meteorological data, population data, spatial data, infrastructure data, health data, social assistance data, emergency reports, and citizen-generated information. Nevertheless, these data are often not processed through integrated analytics that can support prediction, prioritization, or resource allocation. Big data in local disaster governance is therefore still more potential than practice. Kankanamge et al. (2020) show that social media analytics can help determine disaster severity and improve situational awareness

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during flood events. In the Indonesian context, this suggests that public reports, social media posts, and community observations can become valuable data sources if local governments develop verification, classification, and analytical mechanisms.

The study found that disaster data governance should include five basic elements: interoperability, data standards, institutional responsibility, privacy protection, and decision-usefulness. Interoperability ensures that data from different agencies can be connected. Data standards ensure that hazard, population, logistics, shelter, and damage data are recorded in comparable formats. Institutional responsibility clarifies who collects, verifies, updates, analyzes, and uses the data. Privacy protection is needed because disaster data may include personal information, location data, health status, vulnerable group information, and damage reports. Decision-usefulness ensures that data are not collected only for administrative reporting, but are used to support mitigation, preparedness, emergency response, recovery, and public accountability.

These findings demonstrate that the first foundation of smart disaster governance is not technology itself, but integrated data governance. A local government may have sensors, dashboards, applications, and command centers, yet disaster governance will remain fragmented if the data are not interoperable, verified, shared, and connected to decision-making. This strengthens the argument of Simmhan et al. (2018), who emphasize that data-driven IoT architecture must be designed to support urban decision-making. In disaster management, the same principle applies: digital systems must be governed so that real-time information can be transformed into timely and accountable public action.

2) Public Participation as Social Intelligence in Smart Disaster Governance

The findings show that public participation is a critical element of smart disaster governance. Disaster information is not produced only by formal institutions, digital sensors, satellites, or command centers. Citizens also generate important information through community reports, local observations, social media posts, neighborhood networks, volunteer communication, and everyday experience of hazards. In many disaster-prone areas in Indonesia, residents are often the first to observe rising water levels, cracked slopes, damaged drainage, blocked rivers, fallen trees, damaged roads, or early signs of environmental change. This citizen-generated information can strengthen disaster governance when it is connected to formal government systems.

The study found that public participation contributes to disaster governance in at least three ways. First, citizens provide local risk information that may not be captured by formal data systems. This includes information on small-scale hazards, vulnerable households, informal settlements, local evacuation constraints, and community-level infrastructure problems. Second, citizens help disseminate warnings through social networks, religious groups, community leaders, youth organizations, neighborhood associations, and volunteer groups. Third, citizens participate in verification and response by confirming field conditions, assisting evacuation, supporting logistics distribution, and monitoring recovery needs. These roles show that public participation functions as social intelligence in disaster governance.

This finding is consistent with Hadlos et al. (2022), who emphasize that local and indigenous knowledge contributes to disaster risk reduction when it is embedded in community institutions and local decision-making. Firdaus et al. (2023) also show that local wisdom around Anak Krakatau strengthens disaster resilience through the integration of community knowledge and scientific understanding. In the context of smart disaster governance, local knowledge and citizen reporting should not be treated as non-digital or traditional elements that stand outside technological systems. Instead, they should be integrated into digital platforms as complementary sources of situational awareness.

Public participation also strengthens legitimacy and trust. Digital warnings, dashboards, and applications will not automatically produce effective disaster response if citizens do not trust the information, understand the warning, or believe that reporting channels will be followed up by government institutions. The findings indicate that community trust increases when local governments provide feedback, respond to reports, involve citizens in preparedness activities, and communicate risk information in accessible language. This supports Wolff and Muñoz's (2021) argument that crowdsourced disaster data in smart cities is not only technical, but also political and social because it concerns whose information is recognized, verified, and acted upon.

Nevertheless, the findings also reveal several challenges in integrating public participation into smart disaster governance. First, citizen reports vary in quality, accuracy, format, and urgency. Some reports contain clear location data and evidence, while others are incomplete or duplicated. Second, public participation may produce misinformation if reports are not verified. Third, not all citizens have equal access to digital reporting channels due to differences in internet access, digital literacy, age, disability, income, and geographic location. Fourth, local governments do not always have sufficient personnel to filter, verify, classify, and respond to large volumes of citizen-generated information. These challenges show that participation requires governance mechanisms, not merely open reporting channels.

The study found that participatory disaster governance should combine digital and non-digital mechanisms. Digital channels may include mobile applications, social media, call centers, web dashboards, WhatsApp groups, emergency hotlines, and geotagged reporting systems. Non-digital channels may include community leaders, village officials, disaster volunteers, neighborhood associations, religious institutions, and local disaster preparedness groups. Such a hybrid mechanism is important in Indonesia because disaster-prone communities may have unequal digital access. Participation must therefore be designed inclusively so that residents without smartphones, older persons, persons with disabilities, and communities in remote areas can still report risks and receive warnings.

The integration of citizen-generated data also requires verification protocols. Local governments need clear procedures to classify public reports based on urgency, location, hazard type, source reliability, and required institutional response. Reports from citizens should be connected to field verification teams, village governments, command centers, and relevant sectoral agencies. Once verified, citizen reports can become part of the disaster data system and support decisions related to warning dissemination, evacuation, logistics, infrastructure repair, or recovery assistance. This process transforms public participation from informal communication into a structured governance mechanism.

These findings show that smart disaster governance must combine technological intelligence with social intelligence. IoT sensors and big data analytics can provide real-time information, but citizens provide contextual knowledge, local legitimacy, and rapid field confirmation. Public participation is therefore not an additional feature of smart disaster governance. It is one of its core components. Without citizen engagement, smart disaster governance risks becoming technocratic, centralized, and disconnected from local realities.

3) Constructing a Smart Disaster Governance Model for Local Governments

Based on the findings, this study proposes a smart disaster governance model for local governments that integrates IoT-based monitoring, big data analytics, institutional coordination, and public participation. The model consists of six interconnected components: real-time risk monitoring, integrated disaster data platform, big data-based decision support, participatory public reporting, cross-sectoral command coordination, and accountability-based evaluation. These components are designed to transform disaster governance from reactive administration into anticipatory, data-driven, inclusive, and collaborative governance.

The first component is real-time risk monitoring. Local governments need to develop or strengthen IoT-based monitoring systems for hazards that are relevant to their local risk profiles, such as floods, landslides, coastal hazards, volcanic activity, forest fires, droughts, and extreme weather. Sensors, CCTV, automatic weather stations, water-level gauges, rainfall monitors, and geospatial systems should be connected to local disaster management agencies and command centers. Real-time monitoring allows local governments to detect early signs of danger and issue timely warnings. However, this component requires regular maintenance, technical capacity, budget continuity, and clear institutional responsibility.

The second component is an integrated disaster data platform. Disaster data should not remain scattered across sectoral agencies. Local governments need an interoperable platform that connects hazard data, population data, vulnerable group data, infrastructure data, shelter data, logistics data, health data, social assistance data, and citizen reports. This platform should support data sharing among regional disaster management agencies, communication and informatics offices, public works agencies, health offices, social affairs offices, village governments, and community-based actors. Data integration is essential to ensure that decision-makers have a complete and updated picture of disaster conditions.

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The third component is big data-based decision support. Integrated data should be processed into usable information for decision-making. Big data analytics can help local governments identify risk patterns, prioritize high-risk areas, estimate affected populations, allocate logistics, monitor shelters, analyze public reports, and support recovery planning. Big data does not have to begin with complex artificial intelligence systems. At the local government level, it can start with structured dashboards, risk maps, trend analysis, real-time reporting, and simple decision-support tools. The key point is that large and diverse data sources must be transformed into actionable knowledge.

The fourth component is participatory public reporting. Citizens should be able to report hazards, infrastructure damage, emergency needs, evacuation constraints, vulnerable households, and recovery problems through accessible channels. Public reporting should be designed as a two-way communication mechanism. Local governments should not only receive reports, but also provide feedback, verification status, warning information, and follow-up actions. This component ensures that citizens are treated as co-producers of disaster information, not merely as recipients of government instructions. Participatory reporting also strengthens transparency because citizens can observe whether their reports are acknowledged and acted upon.

The fifth component is cross-sectoral command coordination. Smart disaster governance requires a coordination structure that connects data with action. Command centers or emergency operation centers should function not only as information display rooms, but as coordination hubs that bring together disaster management agencies, sectoral offices, village governments, volunteers, emergency services, and community actors. When real-time data and citizen reports enter the system, the command structure must be able to assign responsibilities, mobilize resources, issue warnings, coordinate evacuation, and monitor response. Without this coordination mechanism, digital data will not produce effective disaster governance.

The sixth component is accountability-based evaluation. Local governments need to evaluate smart disaster governance not only by the number of applications, sensors, dashboards, or command centers developed, but by their contribution to disaster risk reduction and public service performance. Evaluation indicators may include warning response time, accuracy of risk information, number of verified citizen reports, evacuation effectiveness, logistics distribution accuracy, reduction of response delays, protection of vulnerable groups, community satisfaction, and transparency of follow-up actions. This component ensures that smart disaster governance remains oriented toward public value rather than technological display.

The proposed model contributes to disaster governance literature by integrating technological, institutional, and participatory dimensions in one framework. Previous studies have examined IoT-based disaster monitoring, big data analytics, social media analytics, and participatory disaster governance separately (Gaire et al., 2018; Shah et al., 2019; Kankanamge et al., 2020; Shahat et al., 2020). This study extends those discussions by positioning smart disaster governance as a local government model that connects real-time data, inter-agency coordination, and citizen participation. In the Indonesian context, this integration is important because local governments often face multi-hazard risks, fragmented institutional arrangements, and unequal digital capacity.

The model also has practical implications. First, local governments need to align smart city programs with disaster risk reduction priorities. Digital infrastructure developed for urban management should also support hazard monitoring, early warning, emergency response, and recovery. Second, disaster data governance must be strengthened through interoperability standards, data-sharing protocols, privacy protection, and institutional responsibility. Third, public participation must be embedded into digital disaster platforms through accessible and inclusive reporting mechanisms. Fourth, command centers must be connected to operational decision-making, not only to information visualization. Fifth, evaluation should focus on whether smart disaster governance reduces risk, improves response, increases public trust, and strengthens resilience.

The central argument of this study is that smart disaster governance is not simply the digitalization of disaster management. It is a governance transformation that integrates technology, data, institutions, and citizens. IoT provides real-time monitoring, big data supports decision-making, and public participation supplies local knowledge and social legitimacy. Their integration enables local governments to move from reactive disaster administration toward anticipatory and collaborative disaster governance. Through this model, smart disaster governance can become a practical framework for improving disaster risk reduction and emergency response in Indonesian local governments.

4. Conclusion

This study concludes that smart disaster governance at the local government level should not be understood merely as the use of digital applications, sensors, dashboards, or command centers in disaster management. Smart disaster governance is a broader governance transformation that integrates real-time digital monitoring, big data-based decision support, institutional coordination, and public participation within one disaster management framework. The findings show that several local governments in Indonesia have begun to adopt digital tools for disaster monitoring, public communication, early warning, and emergency coordination. However, these tools often remain fragmented when they are not supported by interoperable data systems, clear institutional responsibilities, participatory mechanisms, and accountability-based evaluation.

The study found that digital fragmentation remains one of the main challenges in local disaster governance. Hazard data, population data, vulnerable group data, shelter data, logistics data, infrastructure data, health data, and citizen reports are often managed by different institutions without a fully integrated data platform. This fragmentation weakens the ability of local governments to develop a common operational picture during disasters. As a result, disaster decisions may still depend on partial information, manual coordination, and sectoral reporting. The findings indicate that smart disaster governance requires not only digital infrastructure, but also disaster data governance that ensures interoperability, data standards, verification procedures, privacy protection, and decision-usefulness.

The study also concludes that public participation is a central component of smart disaster governance. Citizens are not merely recipients of warnings or beneficiaries of government assistance. They are producers of local risk information, field observers, early reporters, volunteers, and co-actors in disaster response. Citizen-generated information can strengthen situational awareness, especially when integrated with IoT-based monitoring and big data systems. However, public participation must be governed through inclusive reporting channels, verification protocols, feedback mechanisms, and accessible communication systems so that it does not create misinformation, exclusion, or unequal access to disaster services.

The contribution of this study lies in proposing a smart disaster governance model for Indonesian local governments. The model consists of six interconnected components: real-time risk monitoring, integrated disaster data platform, big data-based decision support, participatory public reporting, cross-sectoral command coordination, and accountability-based evaluation. This model shows that IoT, big data, and public participation should not be treated as separate instruments. They must be integrated into a single governance framework that connects technology, data, institutions, and citizens throughout the disaster management cycle.

The novelty of this study is found in its hybrid governance perspective. Previous studies have generally examined IoT-based monitoring, big data analytics, social media analytics, smart city platforms, or participatory disaster governance separately. This study extends those discussions by positioning smart disaster governance as a model that combines technological intelligence, institutional intelligence, and social intelligence. IoT provides real-time hazard monitoring, big data supports risk analysis and decision-making, institutions coordinate resources and responsibilities, while citizens contribute local knowledge, field reports, and social legitimacy. Through this integration, smart disaster governance can move local governments from reactive disaster administration toward anticipatory, data-driven, inclusive, and collaborative disaster risk management.

The findings have several practical implications. First, local governments need to align smart city initiatives with disaster risk reduction priorities, so that digital infrastructure does not function only for general urban services but also supports hazard monitoring, early warning, evacuation, logistics, and recovery. Second, disaster data governance must be strengthened through interoperability standards, data-sharing protocols, privacy safeguards, and clear institutional mandates. Third, citizen participation should be embedded into disaster platforms through accessible reporting mechanisms, community-based verification, and two-way communication. Fourth, command centers should function as coordination hubs that connect data with operational decisions, not merely as information display rooms. Fifth, evaluation should focus on public value, including warning accuracy, response speed, citizen trust, protection of vulnerable groups, and measurable contribution to disaster risk reduction.

This study has limitations. Its qualitative case study design provides an in-depth understanding of governance processes, institutional challenges, and model development, but it does not statistically measure the performance of IoT devices, big data analytics, or digital platforms. The study also focuses on the local government level in Indonesia, while the relationship between local, provincial, and national disaster data systems requires further research. In addition, the implementation of smart disaster governance may vary depending on hazard type, fiscal capacity, technological infrastructure, political commitment, institutional culture, and citizens' digital literacy.

Future research should test the proposed model through comparative studies across different Indonesian regions and hazard types, such as flood-prone cities, tsunami-prone coastal districts, volcanic areas, and landslide-prone rural regions. Further studies may use mixed-method or quantitative approaches to measure the effectiveness of smart disaster governance in improving early warning accuracy, response time, evacuation efficiency, logistics distribution, public participation, and disaster risk reduction outcomes. Research is also needed to examine ethical issues related to disaster data governance, including privacy, cybersecurity, algorithmic bias, data ownership, and the protection of vulnerable groups. Future studies should also explore how artificial intelligence, predictive analytics, community-based sensors, and open data platforms can be developed in ways that are inclusive, accountable, and responsive to local disaster realities.

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