Developing an Integrated Disaster Relief Operations Framework for Logistical Efficiency in Malaysia

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ABSTRACT

Malaysia faces recurring floods and landslides that hamper efforts to improve disaster relief operations (DROs). Floods account for 62.5% of disaster occurrences in Malaysia. Landslides have caused more than 350 deaths and over $1 billion in economic losses since Malaysia's independence. Previous high-impact disasters, including the 2021 nationwide floods, left over 500,000 people affected and caused RM6.1 billion in losses nationwide. National Security Council Directive No. 20 sets up an organizational structure for disaster relief and other activities but does not provide ways to effectively coordinate DROs and other activities. This qualitative case study examines the challenges associated with DROs through semi-structured interviews with 13 key informants working in government and nongovernmental, educational, and other disaster relief organizations. Other data collection methods include field visits to Kelantan and Pahang states and document review. Thematic analysis was used to analyze data. Three key findings related to ineffective disaster logistics include coordination and communication issues and lack of resources. An Integrated Disaster Relief Operations Framework based on the Resource-Based View (RBV), the Sendai Framework for Disaster Risk Reduction (SFDRR), and National Security Council Directive No. 20 is proposed as a solution to these problems. One element of the new framework, the 'FlyChain,' includes the use of blockchain and drone technology to increase transparency and real-time information sharing in disaster logistics. Benefits of the proposed framework include improved decision making and implementation of other reforms to address disaster needs in Malaysia. The proposed framework builds on conceptual frameworks for integrated disaster relief to offer more concrete reforms that can be implemented in Malaysia.

Keywords: Flychain, Disaster Relief Operations, An Integrated Disaster Relief Operations Framework, Logistical Efficiency, Disaster Management, Malaysia

INTRODUCTION

Natural disasters are sudden and unpredictable events that have persistently challenged humanity throughout history. These catastrophic occurrences, such as floods, earthquakes, or landslides, disrupt lives, economies, and infrastructure, causing severe damage and necessitating urgent recovery efforts. The 20th century alone witnessed a dramatic rise in both the frequency and severity of natural disasters worldwide. Torabi et al. (2018) underscore this volatility, reporting over eight million disaster-related fatalities during this period, while Prasad and Francescutti (2017) estimated economic losses in billions of dollars. This upward trend intensified in the 21st century. Between 1980 and 2019, more than 11,000 major disasters occurred worldwide, resulting in over

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two million deaths and $3.64 trillion in damage (United Nations, 2021). Climate change has significantly increased the frequency and intensity of hurricanes, floods, typhoons, tsunamis, droughts, wildfires, and extreme heat events (Kuriansky & Nemeth, 2020). Among these, floods have caused the most extensive damage, accounting for 50% of all natural disasters between 2006 and 2015 (Maqtan et al., 2022). This global surge in hydrological instability has manifested severely across Southeast Asia, necessitating a closer regional investigation into vulnerability.

Recent global statistics underscore this escalating threat. In 2023 alone, the Emergency Events Database (EM-DAT) recorded 399 natural disasters globally, resulting in 86,473 deaths, affecting approximately 93.1 million people, and causing economic losses of US$202.7 billion (Centre for Research on the Epidemiology of Disasters [CRED], 2024). A considerable proportion of these fatalities resulted from a single devastating earthquake in Türkiye and Syria, demonstrating how a single event can trigger widespread regional impacts (Dal Zilio & Ampuero, 2023). Consequently, over the past three decades, global flood-related damage has reached an estimated $18 billion annually, with approximately 6,000 fatalities (EM-DAT, 2024).

According to the United Nations Office for Disaster Risk Reduction [UNDRR] (2025), between 2015 and 2023, an average of over 1.24 billion people were affected by disasters annually. The number has begun to increase again in recent years and remains higher than in the previous decade, rising from an average of 1,158 per 100,000 between 2005 and 2014 to 2,028 per 100,000 between 2014 and 2023 (UNDRR, 2025). As recently as Week 1 of 2026, 25 disaster events were reported across the ASEAN region, including floods, landslides, storms, and wind-related incidents, affecting Indonesia, Malaysia, and the Philippines. EM-DAT further indicates data on the occurrence and impacts of over 27,000 major disasters worldwide from 1900 to the present day (EM-DAT, 2026). Against this backdrop of global and regional vulnerability, Malaysia faces distinctive disaster challenges.

Within this global context, Malaysia faces distinctive disaster vulnerabilities. Despite its geographical location outside the Pacific Ring of Fire, the country is highly vulnerable to hydro-meteorological hazards, particularly floods and landslides. Between 1990 and 2014, floods constituted 62.5% of Malaysia's total disaster events, followed by storms (12.5%), wildfires (8.5%), landslides (8.3%), and other less frequent phenomena (Akter et al., 2019). Flash floods exhibit a distinct seasonal pattern, occurring most frequently during the northeast monsoon (October–January, 49%), followed by the southwest monsoon (June-August, 18%), indicating significant seasonal vulnerability patterns (Maqtan et al., 2025). Furthermore, floods have become an annual, devastating phenomenon in Malaysia. Malaysia's tropical climate and seasonal monsoons expose over 5,000 flood-prone areas nationwide, with Sarawak (1,066), Sabah (798), and Pahang (750) being the most affected (The Star, 2023).

Historically, Malaysia has experienced increasingly severe flood events since 1920 (Shah et al., 2017). Nevertheless, the increasing intensity of recent flooding events highlights growing systemic vulnerability. The catastrophic 2014 flood serves as a grim benchmark, affecting the East Coast States of Kelantan, Terengganu, and Pahang, as well as the West Coast States of Perak and Johor. This disaster affected more than 200,000 victims, resulting in 21 deaths and 8 people still missing (Buslima et al., 2018). It also caused losses of RM2.85 million (Yusoff & Yusoff, 2022). A mere seven years later, demonstrating the increased frequency, another catastrophic flood in December 2021 affected approximately 50,000 victims (Al Jazeera, 2021) and resulted in RM2.851 billion in infrastructure losses (Mhd Noor et al., 2022). Sa'adi et al. (2024) emphasized that these extreme events not only cause immediate damage but also affect the region's resilience and long-term adaptation capacity. More recently, early 2024 monsoon rains forced the evacuation of over 94,000 people and claimed three lives (Leeonis et al., 2025), with forecasts suggesting a potential to surpass the disaster, which displaced a quarter-million and killed 21 (Associated Press, 2024). From late December 2025, eastern Malaysia (comprising Sabah and Sarawak) experienced further floods resulted in the displacement of 3,516 victims to 27 evacuation centers (European Commission's Directorate-General for European Civil Protection and Humanitarian Aid Operations [ECHO], 2026).

Rapid development since the 1980s has complicated urban expansion, often leading to development on unsuitable terrain. Notable events include the 1993 Highland Towers tragedy, which claimed 48 lives (Abd Sahrin & Khanan, 2017), and the December 2022 Batang Kali landslide, which resulted in 30 fatalities, marking

Malaysia's second deadliest landslide disaster (Bernama, 2022). Landslide incidents are increasingly linked to climate change, especially in hilly regions (Noor et al., 2025). The rising frequency and severity of these events put significant pressure on DROs and reveal critical logistical vulnerabilities.

According to Nasir et al. (2023), damaged infrastructure, unsafe conditions, and rugged terrain hampered the prompt delivery of essential supplies. This logistical challenge is a global issue, making it difficult to secure resources for preparedness, mitigation, and recovery (Onyango et al., 2023), particularly in resource-limited, disaster-prone areas. These persistent issues increase the urgent need for robust, proactive disaster recovery planning (Abdullah et al., 2022). With annual global flood damage projected to reach $1 trillion by 2050 (Bui et al., 2019), there exists an urgent need for a practical framework to support DROs and effective disaster preparedness strategies (Nagurney & Nagurney, 2016).

Therefore, Malaysia requires a practical approach to disaster management. Developing an integrated Disaster Relief Operations (DRO) Framework that prioritizes logistical efficiency is urgent, given the frequency and operational complexity of disasters in Malaysia. Given its vulnerability to floods and landslides, such a framework is vital for optimizing resource flow, enhancing communication, and ensuring seamless coordination among stakeholders. Establishing clear roles and responsibilities is critical for minimizing the negative impacts of disasters (Ramli et al., 2024; Ab Malik et al., 2020). This study addresses this gap by proposing an integrated DRO framework that enhances coordination, resource visibility, and real-time decision-making among multiple stakeholders. Specifically, the objective of this study is as follows:

RO1: To explore the key challenges faced by current DROs in Malaysia.

RO2: To investigate how key stakeholders currently address logistical challenges during DROs in Malaysia.

RO3: To analyze the best practices that enhance logistical efficiency in Malaysian DROs.

RO4: To develop an integrated DRO framework to optimize logistical efficiency in Malaysian DROs.

To address the issues outlined above, this study poses four interrelated research questions:

RQ1: What are the key challenges faced by current DROs in Malaysia?

RQ2: How do key stakeholders currently address logistical challenges during DROs in Malaysia?

RQ3: What best practices can enhance logistical efficiency in Malaysian DROs?

RQ4: How can an integrated DRO framework be developed to optimize logistical efficiency in Malaysian DROs?

Problem Statement

Malaysia is approaching a critical stage in strengthening its national resilience against hydro-meteorological hazards (Ramli et al., 2024). As a tropical country, it is highly exposed to floods and landslides, especially during the monsoon season. These disasters create serious economic losses, infrastructure damage, and psychosocial burdens (Kumaresen et al., 2025; Ahmad et al., 2025). Flooding is among the most frequent and damaging disasters in Malaysia, causing major social, economic, and psychological consequences (Ameruddin et al., 2025). Beyond physical destruction, these events also generate severe psychological effects among victims, including anxiety, trauma, emotional distress, and mental disorders (Harun & Akhir, 2025; Ahmad et al., 2025). Research also shows that flood disasters disrupt the everyday lives of affected communities and cause long-term social and livelihood changes (Mustaffa & Khalid, 2021). These impacts extend beyond immediate physical damage and affect the long-term well-being of communities. Over the past decade, rapid urbanization and population growth have further increased the complexity and scale of disasters in Malaysia (Adli Ramli et al., 2025). Expanding urban areas, land-use changes, and population concentration in flood-prone zones have intensified disaster vulnerability (Ramle et al., 2025). These conditions place increasing pressure on the country's disaster response and logistics systems. Consequently, these rising disaster risks exert strong demands

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on its disaster logistics system. However, existing response mechanisms often struggle to deliver aid quickly and coordinate multiple agencies effectively.

Malaysia's vulnerability is also reflected in the World Risk Index. The country's ranking changed from 91st in 2012 to 36th in 2023 (Alliance Development Works, 2012; 2023). This shift represents a significant decline of 55 positions within slightly more than a decade. This trend signals increasing exposure to disasters and reveals weaknesses in preparedness and response capacity. At the global level, research consistently shows that developed countries tend to achieve faster, more efficient disaster responses by investing heavily in disaster management systems and technologies (Rosyidah & Pratikto, 2022; Akhmad et al., 2024). Countries such as Japan and the United States provide strong examples of integrated disaster logistics systems (Adiguzel, 2019). Japan applies proactive logistics strategies and comprehensive disaster response mechanisms (Chittawatanarat, 2026; Keim, 2018). Similarly, the United States uses a structured National Response Framework that coordinates resources from federal, state, and local agencies (Isi et al., 2023; Klasa, 2025).

In contrast, Malaysia's disaster response system still faces structural and operational limitations (Ramlee & Knight, 2025). Several studies suggest that current disaster management approaches in Malaysia are no longer sufficient to address contemporary environmental challenges. Weaknesses in disaster risk reduction governance have been reported, particularly in outdated policies that fail to adapt to a changing climate (Madnor et al., 2024). In addition, poor implementation of flood risk management plans has worsened the impact of recent flood events (Rosmadi et al., 2023). The absence of a comprehensive operational framework for disaster response further complicates these governance weaknesses. Zahari et al. (2022) reported that existing disaster management practices lack a holistic conceptual framework that connects logistics systems, governance institutions, and community participation across the disaster management cycle. Current approaches often operate in isolation, thereby failing to support coordinated response actions (Samsudin et al., 2022). They also tend to emphasize top-down institutional mechanisms while giving less attention to bottom-up community participation (Zawawi et al., 2018; Tahir et al., 2021). These structural gaps weaken coordination among disaster management agencies and limit the effectiveness of relief operations. Empirical evidence from previous disasters further highlights recurring logistical problems in Malaysia. Studies report delays in humanitarian aid delivery, overcrowded evacuation centers, and limited access to essential resources such as clean water and medical assistance (Halizahari et al., 2021; Yazid et al., 2017; Maznieda et al., 2022; See et al., 2017).

Although rescue teams prioritize assisting individuals trapped in affected areas (Faiz et al., 2024), response operations are often constrained by weak drainage infrastructure (Muzamil et al., 2022; Samsuri et al., 2018) and limited enforcement capacity and manpower (Mabahwi & Nakamura, 2020). In addition, incomplete hazard databases, particularly those related to landslide damage, restrict effective risk assessment and mitigation (Bhuiyan et al., 2023; Ramlee & Knight, 2025). These recurring problems indicate that disaster response challenges in Malaysia are not only technical but also logistical and organizational. At the policy level, the National Security Council Directive No. 20 guides Malaysia's disaster management structure. While this directive provides general policy direction and defines the roles of relevant agencies, it lacks detailed operational procedures for disaster response implementation (Zahari et al., 2025). The absence of standardized communication protocols and data-sharing systems often delays decision-making and leads to inefficient resource allocation (Abdullah et al., 2022; Ab Malik et al., 2020; Zakaria et al., 2018). Such institutional fragmentation significantly affects the efficiency of disaster relief logistics.

Malaysia's disaster management system also demonstrates limited technological integration compared to global practices. Modern disaster response increasingly relies on technologies such as geographic information systems (GIS), artificial intelligence, and blockchain-based logistics tracking (Sharma et al., 2020; Alam et al., 2021). However, Malaysia still relies heavily on manual processes and limited digital infrastructure, creating information silos and slowing response operations (Ismail et al., 2019). These technological limitations reduce real-time situational awareness and hinder rapid coordination among disaster response agencies.

Another critical issue relates to community engagement. Public awareness regarding disaster preparedness and response procedures remains low. Limited participation in disaster preparedness programs further reduces

community readiness (Yazid et al., 2017; Nurashikin et al., 2019; Sadeka et al., 2020). Inefficient early warning systems and limited outreach initiatives also weaken preparedness efforts (Alias et al., 2018; Wong et al., 2020). These weaknesses increase uncertainty during DROs and contribute to inadequate community responses (Khuzzan et al., 2017).

Taken together, these structural, logistical, and technological challenges reveal a critical gap in Malaysia's disaster management system. Despite the availability of disaster management frameworks at both global and national levels, they still fall short of supporting truly integrated DROs in Malaysia. More specifically, they fail to bring together real-time operational coordination, multi-agency decision-making, and technology-driven logistics visibility into a single, functioning system. In practice, DROs in Malaysia continue to experience communication breakdowns, delayed information flows, and inefficient resource allocation, particularly during flood crises in highly vulnerable regions such as Kelantan and Pahang. These limitations demonstrate a lack of operational synchronization across institutional, technological, and logistical dimensions, resulting in delayed response and inefficient resource allocation. Therefore, there is a critical need for a framework that goes beyond conceptual coordination and enables the dynamic, real-time integration of stakeholders, resources, and information systems to enhance the effectiveness of DROs.

LITERATURE REVIEW AND THEORETICAL FRAMEWORK

The Resource-Based View Theory

Edith Tilton Penrose introduced ideas that later informed the Resource-Based View (RBV) in the 1950s, explaining how firms use internal resources to support growth. Kor and Mahoney (2004) and Nason and Wiklund (2018) highlighted her emphasis on resource versatility and recombination. In the mid-1980s, Wernerfelt (1984) and Barney (1986) advanced the theory by shifting attention from industry conditions to firm resources as sources of competitive advantage (Nagano, 2020). Barney (1991) later proposed the VRIN framework, which holds that resources must be valuable, rare, inimitable, and non-substitutable to sustain competitive advantage. This framework became central to RBV research and strategic management, guiding firms in using distinctive resources to pursue opportunities and maintain their positions (Carrick, 2013; Jacobsen, 2013; Burr et al., 2016; Nagano, 2020). Subsequent research emphasized firm-specific resources, capabilities, and experience in resource accumulation as sources of competitive advantage and economic rent (Barney & Arikan, 2005; Lockett, 2005). Davis and DeWitt (2021) likewise described RBV as an approach that links strategic resources to firm performance. Researchers have also applied the framework beyond business strategy, including to crisis management (Sohn & Lariscy, 2012), natural resource-based communities, and variation in business performance (Burr et al., 2016).

In disaster management, RBV offers a framework for assessing and deploying resources during disaster response operations (DROs). Studies have applied VRIN criteria to physical assets, human expertise, technology, and organizational processes (Barney, 1991). Research has also examined how supply chain flexibility and inter-cluster cooperation affect humanitarian supply chain performance during DROs (Kwateng et al., 2022). Other work considers resource allocation between life-saving efforts and industrial recovery, and identifies effective resource orchestration as essential to reducing disruptions in healthcare operations (Baltas et al., 2025). RBV has also been applied to urban systems, where resource use can expand response options despite limited funding (Vasudevan, 2021). More broadly, effective resource management can strengthen competitive advantage, improve long-term performance, reduce costs, and increase revenue (Mong et al., 2021). Because resource structures vary, organizations draw on different strategic resources during crises. This perspective is particularly relevant to Malaysia, where frequent natural disasters make a robust disaster relief framework necessary.

The resource-based view (RBV) provides a foundation for strengthening disaster management in Malaysia by showing how organizations can use their existing resources and capabilities to improve preparedness, response, and recovery. This study draws on RBV to develop an integrated disaster relief operations (DRO) framework that addresses complex challenges, particularly logistical inefficiency. Applying RBV can help stakeholders make better use of technology, skilled personnel, and community awareness, improving disaster response logistics (Junaid, 2018). The theory highlights the role of an organization's distinctive resources and capabilities in effective disaster response (Sospeter et al., 2020). In particular, stakeholders can draw on valuable, rare,

inimitable, and non-substitutable (VRIN) resources, including specialized logistics networks, expert personnel, advanced communication technologies, and established community partnerships (Khawka et al., 2025). Strategic use of these resources can streamline supply chains, improve resource allocation, and reduce response times (Komakecha et al., 2025; Geng et al., 2024). Research on healthcare operations and urban systems likewise shows how effective resource management can limit disruption and improve performance when resources are scarce (Baltas et al., 2025; Vasudevan, 2021). This principle is particularly relevant to disaster relief, where stakeholders must deliver aid promptly despite operational constraints. In Malaysia, the RBV can guide systematic assessment of available resources and the development of capabilities that improve DRO preparedness and aid delivery.

The SENDAI Framework for Disaster Risk Reduction

The United Nations established the Sendai Framework for Disaster Risk Reduction 2015–2030 (SFDRR) to

reflect a growing understanding of disaster risk in the 21st century (UNISDR, 2015). Adopted at the Third United Nations World Conference on Disaster Risk Reduction, held in Sendai, Japan, from March 14 to 18, 2015, the framework became a global benchmark for disaster risk reduction (DRR) (UNDRR, 2015). Its implementation sought to reduce disaster risk and related losses to life, livelihoods, health, and the financial, material, social, cultural, and environmental resources of individuals, businesses, communities, and nations. UN member states began implementing the framework in 2015 (Marome & Shaw, 2021); by 2020, five years had passed since its global adoption (Djalante et al., 2020). The SFDRR takes a comprehensive approach to disaster risk management (DRM), linking resilience with human health and development and promoting measures to address disaster risk (UNDRR, 2015). It calls for stronger organizational and community capacity in forecasting, prevention, preparedness, response, and recovery. Building this capacity requires coordination across organizations and sectors, rather than a focus on post-disaster response by individual organizations (Wright et al., 2020). Accordingly, the framework identifies four priorities for action across levels of government, local authorities, and institutions (United Nations, 2015): understanding disaster risk; strengthening DRM governance through clear direction, plans, institutional capacity, and cross-sector coordination; investing in prevention and mitigation through structural and non-structural measures; and enhancing preparedness by integrating DRR into response planning and management (Jones et al., 2021). These priorities also require policymakers and practitioners to base DRM policies and procedures on a comprehensive assessment of susceptibility, capacity, exposure, hazards, and environmental context (United Nations, 2015). The framework further calls on stakeholders at all levels to strengthen response and recovery capacity (Khoshsabegheh et al., 2022).

The United Nations (2015) introduced the “Build Back Better” concept for recovery, rehabilitation, and reconstruction, emphasizing pre-disaster planning and the integration of disaster risk reduction (DRR) into development strategies. The Sendai Framework for Disaster Risk Reduction (SFDRR) addresses hazard exposure, vulnerability, capacity, and hazard characteristics to prevent new risks, reduce existing ones, and strengthen resilience (Iskandar, 2022). It marked a shift toward integrating risk management into economic, social, and environmental activities (Collins, 2018). The SFDRR sets seven global targets and guiding principles to reduce disaster impacts, address underlying risk drivers, and protect development gains (United Nations, 2015). These include reducing global disaster mortality and the number of people affected by 2030, using the 2005–2015 averages as a baseline (Maini et al., 2017). The Framework also calls for integrating DRR into policies, plans, programs, and budgets at all levels, recognizing this as essential to sustainable development (Coetzee et al., 2023). Governments, organizations, and institutions should incorporate this guidance into their disaster risk reduction plans.

For this study, the SFDRR offers a basis for improving logistical efficiency in disaster response operations (DROs). Its priorities support logistics by guiding risk assessment, strengthening coordination, promoting resilient transport and storage infrastructure, and improving preparedness through pre-positioned supplies, trained personnel, and reliable communication systems. Together, these measures can reduce response times and improve aid delivery. The Framework’s targets on infrastructure damage, early warning systems, and international cooperation also support efficient operations by informing resource deployment and enabling cross-border aid. Thus, the SFDRR provides guidance for the timely and effective movement of resources during disaster response.

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Disaster Management in Malaysia

Natural and human-made disasters threaten lives and property, making effective management essential. Emergency response (ER) units need timely access to disaster areas and relevant information (Baharin et al., 2009). Disaster management spans preparedness, response, and recovery, and requires coordination among national, state, and local agencies (Chong & Kamarudin, 2018). In Malaysia, the National Security Council (NSC) established the disaster management framework through Directive No. 20, issued in 1997. The directive defines the policies, roles, and responsibilities of the agencies involved and aims to prepare communities for disasters (Khairilmizal et al., 2016; Chong & Kamarudin, 2018). It reflects the Disaster Management Cycle established by the Federal Emergency Management Agency (FEMA) in 2010. Effective local preparedness also depends on collaboration among statutory bodies, local authorities, and the private sector.

The National Disaster Management Agency (NADMA) implements Directive No. 20 and oversees disaster risk management in Malaysia (Abdullah et al., 2022; CFE-DM, 2022). Its work includes preparedness initiatives, search and rescue operations, and relief efforts (Rahman, 2018). NADMA develops and reviews national policies, supports their implementation, and monitors progress across government agencies. It also conducts disaster exercises, coordinates public awareness programs, and reviews past responses to identify areas for improvement. During emergencies, NADMA manages the Disaster Relief Fund, directs humanitarian assistance, and oversees the Special Malaysia Disaster Assistance and Rescue Team (SMART) (CFE-DM, 2022). These responsibilities support coordination among agencies, effective use of resources, timely responses, and aid delivery to affected communities.

Although Malaysia established NADMA, the NSC's coordinating role remains underutilized (CFE-DM, 2022). The government also formed the Natural Disaster Management and Relief Committee (DMRC) to develop an integrated national system. The DMRC provides strategic leadership at the federal level, while state and district committees manage regional responses, supporting coordination and information sharing among stakeholders (CFE-DM, 2022; Chong & Kamarudin, 2018; Martin, 2019). Under this multi-tiered structure, the National Security Division (NSD) of the Prime Minister's Department manages disaster response and coordinates key functions, including search and rescue, health services, media, logistics, security, welfare, and public warnings (NSC, 2011; Sharif & Hamidi, 2019; Che Hamid et al., 2019). However, the 2004 tsunami revealed gaps in prevention and community involvement in preparedness (Shariff & Hamidi, 2019). In response, Malaysia has emphasized a multi-hazard approach covering all five components of the disaster management cycle (Chong & Kamarudin, 2018).

National Security Council Directive No.20

Malaysia's disaster management framework is governed by National Security Council (NSC) Directive No. 20, issued by the Prime Minister's Department on May 11, 1997. The directive sets nationwide guidelines for disaster management and relief, coordinating government agencies and other stakeholders (Said & Ahmadun, 2017; Ridzuan et al., 2022). It defines the responsibilities and response capabilities of government agencies and nongovernmental organizations (NGOs), and requires agencies involved in disaster response to follow its provisions (Rahman, 2012, 2018; Norizan et al., 2021; National Security Council, 2011; Mabahwi et al., 2020).

The NSC oversees the disaster management system and ensures that relief equipment is available, particularly during floods (Khalid & Shafiai, 2015). During operations, relevant committees assess the incident, prepare response plans, review available capabilities, identify needs for additional assistance, and decide whether to transfer responsibility to a higher authority. They coordinate vertically across administrative levels and horizontally among agencies at the same level, integrating response activities across government departments and participating organizations (NSC, 1997). At the operational level, the National Disaster Control Centre (NDCC) coordinates disaster relief operations (DROs). It receives monitoring and incident reports from technical agencies, including the Department of Irrigation and Drainage (DID), Department of Environment (DOE), Public Works Department (PWD), and Malaysian Meteorological Department (METMalaysia). The NDCC consolidates this information and shares reports with NADMA, the Special Malaysia Disaster Assistance and Rescue Team (SMART), response agencies, NGOs, and volunteers (Che Hamid et al., 2019). It also works

with disaster operation control centres, known as *Pusat Kawalan Operasi Bencana* (PKOB), to coordinate field operations and information sharing.

As Malaysia's lead disaster management agency, NADMA coordinates preparedness and response and briefs the Prime Minister and Deputy Prime Minister, particularly during Level III disasters. The Prime Minister makes decisions based on the situation and NADMA's recommendations (Che Hamid et al., 2019). Disaster response involves three groups of organizations. Primary rescue agencies include the Royal Malaysia Police (RMP), Fire and Rescue Department of Malaysia (FRDM), Malaysian Armed Forces (MAF), emergency medical services, and SMART. Supporting agencies, such as the Civil Defense Department (CDD), assist rescue operations. Relief and recovery organizations include the Social Welfare Department (SWD), PWD, Malaysian People Volunteer Corps (MPVC), Malaysian Red Crescent Society (MRCS), St. John Ambulance, utilities, telecommunications providers, and NGOs. Together, these organizations contribute specialized expertise and logistical support.

At disaster sites, the operations commander establishes red, yellow, and green zones and assigns response units and personnel based on incident severity. All organizations must remain within their assigned zones, while the RMP or MPVC controls access and movement to maintain security (Muda et al., 2020). Agencies must also remain operationally ready, follow their respective SOPs, and submit standard operating rules to the National Security Division. Government agencies, statutory bodies, and private organizations are expected to provide equipment and other logistical support. Disaster management committees may also request and temporarily requisition urgently needed equipment under existing regulations (Muda et al., 2020; Sulaiman et al., 2019). The directive also requires appropriate media coordination at disaster sites. A media control centre should be established in the green zone, equipped with facilities for briefings, conferences, and communication. The relevant information department manages the centre, while information officers coordinate disaster-related communication, media coverage, and public announcements. Media personnel must remain in the green zone unless the Disaster Operation Commander (DOC) authorizes access to the yellow or red zones (Muda et al., 2020). Overall, the directive provides a structured framework for agency coordination, resource mobilization, and disaster response. However, effective implementation requires collaboration among government agencies, NGOs, private organizations, and communities to reduce operational confusion, resource wastage, and conflicting responsibilities.

Despite this framework, NSC Directive No. 20 has several limitations. Its broad, multi-hazard approach does not specifically address flood risk management, and its reliance on regulations not designed specifically for flood control weakens its effectiveness in addressing flood-related risks (Hamin et al., 2012; Ridzuan et al., 2022). Although the directive emphasizes institutional coordination, it does not clearly define citizen participation or community preparedness (Ridzuan et al., 2022). Coordination and communication among agencies remain challenging, while local authorities face constraints in manpower, equipment, and authority to implement flood management plans effectively (Mabahwi et al., 2022; Rosmadi et al., 2023). Low regulatory compliance, negative attitudes among officials, administrative barriers, and unclear guidance further undermine disaster preparedness and response (Roosli, 2010). In addition, insufficient emphasis on public awareness and community engagement limits preparedness at the grassroots level (Mhd Noor et al., 2022; Ridzuan et al., 2022). These shortcomings indicate that the directive's broad scope, fragmented regulatory support, limited community integration, and implementation challenges constrain its effectiveness in managing floods in Malaysia.

Challenges in Malaysia's Disaster Management

Disaster management in Malaysia has evolved to incorporate traditional practices and modern technologies for mitigating natural and human-caused hazards. Geographic information systems (GIS) and remote sensing (RS) support all four phases of disaster management: mitigation, preparedness, response, and recovery. They help agencies analyze and visualize large, cross-agency datasets, reduce hazard exposure and vulnerability, and strengthen emergency preparedness and response (Abdullah et al., 2022). GIS provides spatial analysis that helps clarify where and how disasters occur and informs response and relief planning. RS uses sensors on satellites and aircraft to monitor the Earth's surface and atmosphere, supporting the prediction, detection, assessment, and mitigation of disasters (Teodoro & Duarte, 2022). Its broad coverage and continuous, all-weather operation also enable environmental monitoring and resource surveys (Kaku, 2019). Satellite and aerial data can further support

rapid impact assessments and timely responses. Despite these benefits, Malaysia does not fully use GIS, RS, or information systems such as early warning systems to reduce disaster impacts (Abid et al., 2021). Their effectiveness also depends on sensors, internet access, software, databases, and skilled interpreters (Abdullah et al., 2022). More broadly, disaster response organizations (DROs) face challenges in decision-making, resource allocation, and coordination.

Coordination is further complicated by the uneven use of top-down and bottom-up planning approaches (Chong & Kamaruddin, 2018). Disagreement among flood management agencies reflects a systemic bias in flood management (Zakaria et al., 2018; Tahir et al., 2021). Agencies often have different priorities and methods, while coordination mechanisms remain limited (Nor et al., 2024). This also makes it difficult to align NGOs' strengths and capabilities (Mohd et al., 2018), leaving vulnerabilities in the wider disaster management system. These problems are compounded by the lack of disaster-specific policies: Malaysia often applies uniform policies across different hazards, including floods, particularly during emergency response (Rahman, 2018; Chong & Kamarudin, 2018). Illias et al. (2021) similarly found that disaster management efforts have not focused sufficiently on flash floods or considered all four phases from a global perspective. Agencies tend to prioritize warnings, emergency relief, and rehabilitation (Yusoff et al., 2018), although flood warning systems have limited impact on reducing damage (Mohammed et al., 2018). Studies have also identified ineffective early warning systems (Alias et al., 2018; Wong et al., 2020) and outdated, inefficient drainage infrastructure (Samsuri et al., 2018).

Malaysia also lacks a robust framework for developing disaster-resilient and sustainable communities (Sulaiman et al., 2019). Although the country enacted the Solid Waste and Public Cleansing Management Act 2007 (Act 672), regulations remain insufficient, and industry practitioners have not effectively adopted government policies (Zawawi et al., 2018). Consequently, institutional resources for flood risk reduction are unreliable, and local planning regulations do not adequately reflect local flood vulnerability (Karki, 2020). Mabahwi and Nakamura (2020) also noted the absence of a specific law governing NADMA's role in flood risk management. Directive No. 20 provides disaster management guidelines but does not establish a comprehensive approach to flood risk management (Yusoff et al., 2018). Finally, overlapping responsibilities and poor resource management have caused confusion among organizations involved in disaster management (Wong et al., 2020).

Logistical Efficiency in Disaster Relief Operations

Natural disasters are increasing in frequency and intensity worldwide due to climate change and urban development in hazard-prone areas (Boccard, 2021; Elliot et al., 2025). This trend highlights the importance of efficient Disaster Relief Operations (DROs), where logistics directly affects survival, recovery, and resilience. Unlike commercial logistics, which prioritizes cost and profit, disaster logistics focuses on speed, adequacy, equitable distribution, and human welfare (Van Wassenhove, 2006). Although the claim that humanitarian logistics accounts for 80% of disaster relief efforts has limitations in cost accounting, it highlights logistics as a major component of relief operations (Cozzolino, 2012). Disaster logistics covers procurement, transportation, storage, and distribution to reduce human suffering (Baidoo, 2018). However, systemic inefficiencies and unpredictable disaster conditions often limit its effectiveness (Abu-Alhaija et al., 2025). These challenges are particularly relevant to Malaysia, which is vulnerable to floods and landslides (Mabahwi & Nakamura, 2024). Although Malaysia has established disaster management frameworks, existing research has largely examined policy, institutional arrangements, and community preparedness (Ab Malik et al., 2020; Negi, 2022). This leaves a need for further research into logistical efficiency within Malaysia's disaster response system.

International research identifies coordination, resource availability, communication, and technology adoption as key factors influencing logistical efficiency. Optimization models address operational constraints and competing demands during disaster response. Ershadi and Shemirani (2022), for example, developed a multi-objective model that considers vehicle capacity, injury categories, and updated information to minimize unmet demand. Similarly, Maroof et al. (2023) reviewed Vehicle Routing Problem (VRP) models and highlighted the importance of route planning, fleet allocation, and delivery time windows. Qazi (2026) further emphasized the role of resilient logistics capabilities in strengthening preparedness and response. These studies show that effective logistics requires both sound planning and the capacity to adjust to changing conditions. Technology can support this adaptability by improving information visibility, coordination, and resource allocation. Wagner

et al. (2024) found that Radio Frequency Identification (RFID) improves inventory tracking and coordination. Data analytics and machine learning can strengthen forecasting, reduce duplication, and support resource deployment (Singh et al., 2024; Kalu-Mba et al., 2025). Wang et al. (2025) applied the EW-TOPSIS and GM-Markov framework to assess supply chain resilience during public emergencies, while Omojola and Okeke (2025) highlighted the use of predictive analytics in humanitarian resource allocation. Drones also offer potential for delivering supplies to inaccessible areas, although usability and security concerns remain (Edwards et al., 2023). More broadly, digital transformation can strengthen disaster preparedness, but implementation costs, field conditions, and ethical oversight remain significant barriers (Ólafsson, 2024; Atulugama, 2025).

International comparisons provide further insight into disaster logistics capabilities. Japan and the United States are frequently cited for their established disaster governance, logistics infrastructure, and preparedness investments (Farhanrika et al., 2023). Japan uses established frameworks and integrated emergency logistics centers to support humanitarian logistics (Chittawatanarat, 2026; Kokaji & Kainuma, 2018). The United States National Response Framework enables scalable responses through modular logistics and multilevel governance (Keim, 2018). Both countries also use operational feedback and advanced analytics to improve resource planning (Adeleye et al., 2024; Seaberg et al., 2017). However, Japan continues to face coordination gaps, communication difficulties, and resource shortages, demonstrating the need for continuous training and system evaluation (Kokoc et al., 2025). These challenges show that established systems require ongoing improvement.

Indonesia provides a relevant regional comparison because it faces disaster risks and logistical constraints similar to those found in other ASEAN countries. Its challenges include fragmented communication, inadequate training, and insufficient resources for local responses (Galorio, 2025; Kurniawan, 2025; Shin et al., 2025). Although the ASEAN Coordinating Centre for Humanitarian Assistance (AHA Centre) supports regional coordination, systemic challenges persist (Rahmadhani et al., 2025). Indonesia's experience illustrates that regional mechanisms alone cannot resolve operational and capacity gaps. Within ASEAN, logistics performance varies considerably. Singapore benefits from strong infrastructure and technology integration, while Thailand and Vietnam are commonly described as mid-tier performers with varying infrastructure and logistics management capabilities (Makmor et al., 2023; Vu, 2019). The World Bank's 2018 Logistics Performance Index ranked Singapore seventh, Thailand 32nd, and Vietnam 39th among 160 countries (Makmor et al., 2023; Vu, 2019). Vietnam has benefited from export growth and infrastructure development but continues to face regulatory and strategic planning constraints (Makmor et al., 2023; Vu, 2019). These differences provide context for assessing Malaysia's regional logistics capacity.

Despite these variations, ASEAN countries continue to face challenges in coordinating resources and financing disaster responses. Nurhidayah et al. (2025) highlighted inadequate financial and resource mobilization despite the ASEAN+3 Disaster Risk Financing Action Plan 2023–2025. Such constraints complicate responses to increasingly complex climate-related disasters. Taken together, international and regional evidence indicates that logistical efficiency depends on effective coordination, adequate resources, reliable information, and appropriate technology. These findings establish the need to examine the specific operational and governance barriers affecting Malaysia's disaster relief system.

Blockchain in Disaster Relief Operations

Blockchain technology, introduced by Nakamoto in 2008, provides a secure system for recording digital transactions (Sreelakshmi & Chandra, 2022). As a form of Distributed Ledger Technology (DLT), it stores transaction records across networked computers (Lardo et al., 2022). Transactions are grouped into chronologically linked blocks and protected by cryptographic algorithms, making recorded data difficult to alter (Chen et al., 2021; Heinrich et al., 2019). Its main features include decentralization, immutability, and disintermediation (Javadpour et al., 2023). These features support smart contracts, secure information sharing, and data reliability (Sobha & Sridevi, 2019; Varriale et al., 2021; Erol et al., 2022). Blockchain also supports supply chain governance and sustainability objectives (Giganti et al., 2024). Its shared ledger enables timely information exchange, which supports decision-making during emergencies (Sreelakshmi & Chandra, 2022).

In disaster management, blockchain can improve coordination, resource allocation, and material tracking by providing transparent information sharing among stakeholders (Panesir, 2018; Bhatelia et al., 2020; Poonia et

al., 2021). Smart contracts can support information exchange and coordination, helping responders plan operations and deliver aid promptly. These functions can strengthen stakeholder collaboration and trust in disaster relief operations (Sobha & Sridevi, 2019; Wang & Chen, 2022). L'Hermitte and Nair (2021) further proposed integrating commercial logistics resources with blockchain to mobilize relief supplies and strengthen trust between commercial organizations and emergency responders.

Several studies have examined blockchain applications for crisis coordination and resource deployment. Bhat et al. (2021) highlighted its potential to improve trust, transparency, and resource coordination, while Bayat et al. (2021) discussed decentralized information sharing for data integrity, resource tracking, and victim identification. Sreedevi et al. (2021) proposed a decentralized application combining blockchain, cloud computing, and the Internet of Things (IoT). Its smart contracts automate responses to disaster management requests and support organizational collaboration. Li and Shang (2022) developed a model to improve data transmission and encryption, reporting data protection exceeding 90% in disaster scenarios.

Other systems address communication and data-sharing constraints during emergencies. Das et al. (2022) introduced ReliefChain, which uses Delay-Tolerant Networking (DTN) and smart contracts to maintain data transfer under limited connectivity, track relief needs, and improve resource allocation. Wasserman (2022) proposed a two-layer Blockchain-based Data Access Ecosystem (BDAE) that incorporates data-sharing incentives and data quality services for systems affected by infrastructure limitations.

More recent research has examined blockchain security, transparency, and practical implementation. Kolhatkar et al. (2023) identified its potential to improve traceability, security, and operational efficiency. Habib et al. (2025) found that blockchain-based systems can support decentralization and stakeholder collaboration in earthquake disaster management. Lathkar et al. (2024) developed a system using ReactJS, Web 3.0, and Solidity smart contracts on Ethereum to improve donation transparency and simplify donation processes. Similarly, Parildar et al. (2023) developed a prototype with a mobile application for user registration and status updates and a desktop application that allows relief organizations to access user data through the Ethereum Sepolia test network.

Other approaches focus on secure data exchange and disaster recovery. Ahmed (2023) proposed an architecture based on Hyperledger Fabric and smart contracts, while Divya and Samraj (2024) applied machine learning to predict storm severity and highlighted the importance of data security and transparency. Badarudin et al. (2020) proposed a federated blockchain network combining smart contracts and digital wallets to improve connectivity between responders and donors. Samir et al. (2019) identified weaknesses in centralized systems and advocated blockchain to strengthen trust. Demir et al. (2018) developed a blockchain-based disaster recovery system to track restoration activities, improve transparency, and support dispute resolution.

Overall, these studies range from conceptual frameworks to functional prototypes and demonstrate blockchain's potential to improve information security, resource tracking, coordination, and stakeholder trust in disaster management. However, the effectiveness of these applications depends on their suitability for operational conditions, including limited connectivity and infrastructure constraints.

Drone in Disaster Relief Operations

Technological advancements in edge computing and Artificial Intelligence (AI) have led to increased use of small Unmanned Aerial Systems (sUAS) across diverse applications, particularly in emergency response (Bernal et al., 2024). Central to this evolution is the Internet of Drones (IoD), an architectural framework that facilitates the autonomous operation of Unmanned Aerial Vehicles (UAVs) across varied environments (Floreano & Wood, 2015). By ensuring secure communication between platforms and operators, the IoD optimizes disaster management efforts (Derhab et al., 2023). For instance, enhanced UAV-ground station connectivity has significantly improved Search and Rescue (SAR) operations (Becerra, 2019).

In the event of a catastrophic event, it would be highly beneficial for both victims and first responders to have access to a UAV network capable of autonomous deployment and communication services (Alawad et al., 2023). These integrated systems mitigate operational risks during emergency missions by providing critical, rapid-

response capabilities (Avi & Quaranta, 2023). Studies have shown that drones enhance disaster response in multiple ways. According to Quero & Martinez-Carranza (2025), drones have marked a significant advancement in search and rescue (SAR) operations, offering numerous notable advantages due to their versatility, rapid deployment, and high mobility. For instance, Tariq et al. (2018) developed DronAID, a system that used cameras and sensors to detect survivors in disaster zones.

Additionally, drones also locate victims buried under rubble using noise, vibration, and heat-sensing technologies (Thavasi & Suriyakala, 2012; Daud et al., 2022). They can cover vast areas quickly, potentially saving many lives in a brief time (Alotaibi et al., 2019). The drones also delivered medical supplies to remote areas with limited road access (Mesar et al., 2018), reducing costs and response times (Chari & Novukela, 2023; Sharma & Sharma, 2024). Their compact size addressed inaccessibility issues where land transport (Rabta et al., 2018), such as by boat or helicopter (Hashim & Tamizi, 2018), is impractical. Consequently, drones proved to be more cost-effective than traditional methods, such as helicopters, for humanitarian aid delivery (Chari & Novukela, 2023). Turgut & Seker (2023) predicted that drones would replace traditional methods in commercial activities by 2028, driven by technological advancements. These findings highlighted the IoDs as an essential tool in modern disaster management, thereby improving the efficiency and timeliness of relief efforts.

The use of drones in disaster management has gained significant attention recently due to their ability to respond quickly to crises. Drones equipped with advanced features such as ballistic recovery systems, real-time video transmission, and substantial payload capacity offer swift deployment to disaster zones (Hasan et al., 2018). Furthermore, Bushnaq et al. (2022) highlight advancements, such as the low cost and flexibility of UAVs, which enable the deployment of innovative and dynamic communication and sensing solutions in high-risk regions within a limited timeframe. In addition, comprehensive guides now exist covering drone construction, pre-disaster preparation, and post-disaster response strategies (Nikhil et al., 2020). Beyond their rapid response capabilities, drones also support effective communication in affected areas through innovative solutions like ServalMesh, which constructs secure mesh networks using mobile phones (O'Keeffe et al., 2018). Building on this concept, Ganesh et al. (2021) introduce UbiQNet, a system that uses drones equipped with mesh networking to enable victims to report directly to first responders.

Additinally, drones can be equipped with object-detection algorithms to enhance their capabilities for disaster management. Systems such as EagleEYE and LUNA have shown promising results in real-time object detection and autonomous disaster response (Ardiansyah et al., 2020; Xu et al., 2019). Advanced algorithms, such as the hybrid Owl Optimization Algorithm, optimize drone trajectories and ensure data integrity (Anjum et al., 2022). These optimization techniques enhance the efficiency of drone-based disaster relief. The 2EVRP-MOD model by Redi et al. (2020) and the hierarchical spectrum-sharing approach by Shamsoshoara et al. (2020) illustrate the potential of optimization in this field. Effective management frameworks and knowledge-based systems further improve the quality and efficiency of relief missions (Hewett & Puangpontip, 2022). In contrast, innovative systems like DroneGo, designed by Hu (2019), demonstrate drones' ability to deliver medical supplies and other necessities to affected regions. Additionally, autonomous aerial robots have been proven to significantly increase the efficiency of search and rescue missions while reducing operational costs and response times (Sangeeta et al., 2023).

Drones in disaster management offer numerous advantages, including enhanced situational awareness, faster response times, reduced risk to responders, increased efficiency through task automation, and improved logistics (Krichen & Abdalzaher, 2023). FPV drones, equipped with cameras and video transmitters, further enhance response efficiency by streaming live footage of affected areas (Pragna et al., 2023). Meanwhile, in disaster remote sensing, deep learning techniques have proven valuable for image analysis and object detection (Toby et al., 2022). Object detection algorithms, such as YOLOv4, have successfully detected humans in flood-affected areas (Gaur & Kumar, 2023), while CNN models can categorize diverse types of disasters (Khemaissia & Soufi, 2023). Optimization of UAV placement and trajectory planning is crucial for efficient disaster response, as demonstrated by approaches such as the deterministic centroid-based UAV placement and collaborative zone exploration strategy, as well as the HFFPSO method (Seddiki et al., 2023; Chandran & Vipin, 2023). The feasibility of using UAVs for crisis mapping has been validated, providing valuable insights for situational awareness and damage assessment (Halbgewachs et al., 2023).

UAV networks can also be designed to provide efficient communication in disaster response, as shown by Yang et al. (2023). Furthermore, several studies have highlighted the benefits of drones in disaster response, such as efficient data analysis, improved safety in aid delivery, and enhanced situational awareness, as noted by Merkle et al. (2023), Saji et al. (2023), and Maghfiroh et al. (2023). Ongoing research continues to explore

the design and testing of drone systems for disaster response, addressing challenges (stability, human detection, and communication) as reported by Krupakar et al. (2024), Ishiwatari (2024), Kowshika et al. (2024), and Goel & Gupta (2024). Additionally, studies have demonstrated the effectiveness of advanced techniques, such as infrared image-based object detection (Vedanth et al., 2024), formal verification of drone mission safety and security (Sowmya et al., 2024), and signal-processing techniques (Papyan et al., 2024), in addressing challenges in drone-based disaster response.

Despite these benefits, drone-based disaster response still faces challenges involving stability, human detection, and communication (Krupakar et al., 2024; Ishiwatari, 2024; Kowshika et al., 2024; Goel & Gupta, 2024). Recent research has examined infrared image-based detection, formal verification of mission safety and security, and signal-processing methods to address these issues (Vedanth et al., 2024; Sowmya et al., 2024; Papyan et al., 2024). Overall, UAVs can strengthen disaster response through faster assessment, rescue support, communication, and supply delivery. However, these capabilities require reliable coordination, secure communication, and effective operational planning to improve relief outcomes.

METHODOLOGY

Research design

The study adopted a qualitative case study design within a constructivist orientation. This approach was selected to examine how disaster-management stakeholders understand and experience logistical challenges in their operational context. The study focused on information-rich accounts and the relationships among institutional arrangements, field practices, and resource constraints (Kaushik & Walsh, 2019; Yin, 2018).

Participants and setting

Purposive sampling was used to recruit 13 informants with experience in disaster relief operations. They represented government agencies, non-governmental organizations, academia, medical teams, volunteers, and community leadership. Field observations focused on flood- and landslide-prone areas in Kelantan and Pahang. These participants provided information-rich perspectives across several stakeholder groups; however, the sample was small and did not represent every administrative level or disaster-prone region in Malaysia. The findings should therefore be interpreted as context-specific qualitative evidence rather than a nationally representative account. Further research involving additional federal, state, district, private-sector, and community stakeholders would help assess the transferability of the findings

Data collection

The study drew on semi-structured interviews, field observations, and document analysis. Interviews explored operational challenges, current stakeholder responses, relevant practices, and opportunities to improve logistical efficiency. Field observations provided contextual information about conditions in disaster-prone areas. Documents supplied policy and technical context and helped compare participant accounts with existing arrangements. The thesis reports that data collection continued until saturation was achieved.

Data analysis and ethics

Interview data were organized and coded with ATLAS.ti. The analysis involved open coding, grouping related codes, developing categories, and identifying recurring themes. Communication, coordination, and resource allocation, including manpower and equipment, emerged as central themes. The use of interviews, observations, and documents supported comparison across sources. The researcher reports that informed consent was obtained and that participant privacy was protected through anonymized identifiers. The study provides a qualitative account of stakeholder experience and informs the design of a proposed framework. It does not report a

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controlled test of FlyChain, a quantitative estimate of logistical improvement, a simulation of system performance, or a cost-benefit evaluation. The findings therefore identify operational needs and inform framework development, but they do not establish that FlyChain is technically feasible, cost-efficient, scalable, or effective in live disaster conditions.

RESULTS

Objective 1: Key Challenges in Malaysian DROs

The first research objective (RO1) examined the key challenges affecting Disaster Relief Operations (DROs) in Malaysia. Analysis of interviews with 13 key informants, field observations, and document analysis identified three main challenges: communication breakdowns, inadequate coordination, and resource constraints. These challenges disrupted relief activities and delayed the delivery of assistance to affected communities. The findings are consistent with earlier studies on disaster management challenges in Malaysia (Mabahwi & Nakamura, 2020; Muzamil et al., 2022). Communication problems affected information sharing and operational decision-making during DROs. Informants reported incomplete information about disaster conditions, unsafe routes, and road accessibility. Communication difficulties also limited coordination between response teams and delayed the delivery of assistance. In some cases, the lack of reliable information about flood routes increased risks for rescuers and affected communities. These findings align with Mabahwi and Nakamura (2020), who identified communication problems among agencies involved in flood response in Malaysia.

Coordination was another major challenge, particularly among government agencies at the federal, state, and district levels. Different responsibilities and fragmented command structures complicated joint operations. Informants also reported that bureaucratic procedures and restrictions on access to disaster areas prevented some NGOs and volunteers from delivering supplies promptly. These barriers delayed aid distribution and limited the effective use of available assistance. The findings support previous research identifying weak coordination as a persistent challenge in Malaysian disaster management (Muzamil et al., 2022). Limited manpower and equipment further reduced the effectiveness of DROs. Informants described shortages of trained personnel, rescue teams, boats, and suitable facilities. In one reported incident, a volunteer had to assist a woman giving birth on a boat because medical personnel were unavailable. This example illustrates how staff shortages can force volunteers to perform tasks beyond their training. Limited equipment and inadequate facilities also made rescue operations and the delivery of essential supplies more difficult. These resource constraints weakened the timeliness and efficiency of disaster relief.

Overall, RO1 identified three interconnected challenges in Malaysian DROs: communication breakdowns, coordination difficulties, and shortages of manpower and equipment. Poor information flow delayed decisions, fragmented coordination complicated joint operations, and limited resources constrained rescue and aid delivery. These findings reinforce earlier research on communication and coordination weaknesses in Malaysian disaster response (Mabahwi & Nakamura, 2020; Muzamil et al., 2022).

Objective 2: Stakeholders' Strategies to Address DRO Challenges

The second research objective examined how stakeholders address logistical challenges during Disaster Relief Operations (DROs) in Malaysia. The findings identified three main strategies: communication enhancement, coordination improvement, and resource optimization. These strategies involved information sharing, inter-agency collaboration, personnel training, community preparedness, early warning systems, and advanced resource mobilization. Although these initiatives helped improve disaster response, some remained fragmented and did not fully resolve the underlying logistical and coordination problems. Greater integration is therefore needed to strengthen the effectiveness and resilience of DROs.

Communication Enhancement Strategies

Stakeholders used informal networks, field representatives, and centralized communication channels to improve information sharing during disasters. For example, RM3 used boats to reach isolated areas, identify affected communities, and inform other NGOs about locations requiring assistance and the number of people in need.

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As a representative of the Malaysian Relief Agency (MRA), RM3 also served as a main contact point for NGOs entering affected areas (RM3:S5/L63-65). The MRA also coordinated NGO activities through the Pusat Kawalan Operasi Bencana (PKOB), helping centralize information and improve coordination (RM3:S5/139-141). Similarly, RM7 relied on personal networks to obtain assistance from other organizations, including the Maghfirah Foundation (RM7:S2/L462-464). These approaches helped stakeholders share information and direct assistance to affected communities more effectively. Overall, the findings show that timely and accurate information sharing is essential for coordinating relief activities, allocating resources, and supporting safe operations. Clear communication channels can help reduce delays and improve logistical efficiency.

Coordination Improvement Initiatives

Stakeholders improved coordination through partnerships among government agencies, NGOs, and other organizations. A key initiative was Rakan NADMA, established by the National Disaster Management Agency (NADMA) in 2016. The initiative brought together 72 registered NGOs with different skills, equipment, vehicles, and operational capabilities. These complementary resources supported joint efforts to assist disaster-affected communities (RM11:S4/L359-379). NADMA also maintained a database of NGOs to facilitate the mobilization of assistance when required (RF8:S3/L53-57). When federal resources were insufficient, federal and state governments could coordinate resource sharing across states. This arrangement helped organize the contributions of organizations responsible for food distribution, healthcare, evacuation, and other relief activities (RF8:S3/25-29). Collaboration also extended to partnerships between relief organizations, universities, and polytechnics. RM3 highlighted cooperation with partner organizations, while RM7 described collaboration with higher education institutions to support disaster-related activities (RM3:S5/L635-636; RM7:S2/L443-448). These findings indicate that partnerships and shared resources can improve coordination and aid delivery. However, their effectiveness depends on clear responsibilities, information sharing, and coordinated action among participating organizations.

Resource Optimization

Stakeholders addressed resource constraints through two main approaches: improving manpower capacity and making better use of equipment and technology.

Manpower

Training was a key strategy for addressing shortages of skilled personnel. RM13 described a customized training module covering medical, rescue, and underwater operations. The training was adapted to participants' roles and responsibilities, allowing personnel to develop the skills required for specific operational tasks (RM13:S5/L283-289). Stakeholders also strengthened community preparedness through community-based disaster risk management. The Kampung Siaga 221 initiative encouraged residents in disaster-prone areas to prepare for emergencies and understand their responsibilities during disaster response (RM13:S5/L220-228). Other initiatives included volunteer training and Training of Trainers (TOT) programmes, which developed basic rescue skills and disaster awareness among volunteers and community members (RM3:S5/L348-351). Additional manpower support came from volunteers who assisted with relief activities when personnel were limited (RM5:S2/L31-35). Local communities also conducted rescue drills and learned when to contact professional responders, helping them provide initial assistance before rescue teams arrived (RF8:S3/255-258). These findings suggest that targeted training, volunteer participation, and community preparedness can help reduce manpower shortages and strengthen local response capacity. Adequate training remains important to ensure that personnel and volunteers can perform their assigned roles effectively.

Equipment

Equipment shortages limited disaster assessment, evacuation, and relief delivery. To address these constraints, stakeholders adopted sensor-based early warning systems and mobilized equipment before disasters occurred. Sensors, satellites, and other instruments were used to monitor conditions in disaster-prone areas, including rising water levels and potential hazards (RM9:S3/L177-182). Stakeholders also positioned transportation assets in advance to support faster emergency responses. Firefighters, police, and medical teams prepared their

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transportation resources before floods, enabling them to reach affected areas more quickly when emergencies occurred (RM3:S5/L17-20). These measures supported preparedness and helped reduce delays caused by limited equipment availability. The findings highlight the importance of combining early warning technology, advance planning, and resource mobilization. Ensuring that essential equipment is available when needed can improve evacuation and relief operations.

In conclusion, the findings for RO2 identify three strategies used by Malaysian stakeholders to address logistical challenges in DROs. First, communication enhancement involved centralized coordination through PKOB, field information sharing, and contact networks. Second, coordination improvement involved partnerships such as Rakan NADMA, NGO databases, intergovernmental cooperation, and collaboration with other organizations. Third, resource optimization focused on personnel training, community preparedness, volunteer involvement, sensor-based early warning systems, and advance equipment mobilization. Although these initiatives supported disaster response, the findings indicate that existing efforts were not sufficiently integrated to resolve persistent logistical and coordination problems. This highlights the need to connect stakeholder initiatives with suitable technologies and established disaster management frameworks. The next section examines best practices and technological applications relevant to improving logistical efficiency in Malaysian DROs.

Objective 3: The Best Practices to Enhance Logistical Efficiency

This section identifies best practices for improving logistical efficiency in Malaysian Disaster Relief Operations (DROs). The document analysis examined 80 academic papers published between 2018 and 2025. The findings focused on three areas: unmanned aerial vehicles (UAVs), blockchain technology, and their integration into a proposed system called FlyChain. These technologies have the potential to improve communication, coordination, and resource allocation during disaster response.

The Role of Drones in DROs

Drones support disaster relief by enabling rapid response, search and rescue, aerial assessment, and the delivery of essential supplies. They are useful in areas affected by floods and landslides, where damaged infrastructure limits ground access (El-Sakka et al., 2025; Faiz et al., 2024; Hashim & Tamizi, 2018; Bernal et al., 2024). They also help responders assess disaster conditions and coordinate operations more effectively (Eshtaiwi & Ahmed, 2024). The Internet of Drones (IoD) framework connects UAVs with ground stations to support search-and-rescue operations, early warnings, and damage assessments (Floreano & Wood, 2015; Derhab et al., 2023; Becerra, 2019). Drones can deliver medical supplies to remote locations faster and at a lower cost than helicopters. Their mobility is particularly valuable when floods make roads and other transport routes inaccessible (Mesar et al., 2018; Chari & Novukela, 2023; Rabta et al., 2018).

In Malaysia, drones can support last-mile delivery, provide aerial images, and supply real-time information for disaster-related decisions. These capabilities improve situational awareness, shorten response times, and reduce risks to rescue personnel (El-Sakka et al., 2025; Krichen & Abdalzaher, 2023). Technical features further improve drone operations. Ballistic recovery systems and real-time video transmission support deployment in disaster areas (Chaari et al., 2024; Hasan et al., 2018). Drones can also restore communication when existing networks fail. Serval Mesh enables mobile phones to form secure mesh networks, while UbiQNet supports direct communication between affected people and first responders (O'Keeffe et al., 2018; Ganesh et al., 2021). High-resolution cameras and object-detection algorithms help drones identify survivors and damaged infrastructure. Systems such as EagleEYE and LUNA support autonomous responses and faster decision-making (Muzammul et al., 2024; Ardiansyah et al., 2020; Xu et al., 2019). Drone performance can also be improved through trajectory optimization and placement methods, including the Owl Optimization Algorithm, deterministic centroid-based placement, and HFFPSO (Anjum et al., 2022; Seddiki et al., 2023; Chandran & Vipin, 2023). The 2EVRP-MOD model supports drone-based mapping and vehicle routing, while hierarchical spectrum sharing helps manage communication between UAV networks and terrestrial networks (Redi et al., 2020; Shamsoshoara et al., 2020).

Other systems support medical delivery, search and rescue, and remote sensing. DroneGo focuses on delivering medical supplies and essential items, while FPV drones transmit live footage to support operational decisions

(Hu, 2019; Sangeeta et al., 2023; Pragna et al., 2023). Deep learning and infrared image analysis further support image interpretation and survivor detection (Toby et al., 2022; Vedanth et al., 2024). Formal verification and signal-processing techniques can improve mission safety, security, and operational performance (Sowmya et al., 2024; Papyan et al., 2024). Drones can also map damaged areas and detect people when conventional communication infrastructure is unavailable. YOLOv4 has been used to detect people in flood-affected areas, while YOLOv8 and DETR have been assessed using thermal images (Gaur & Kumar, 2023; Kannan et al., 2024). UAVs also support crisis mapping and can establish temporary communication networks without waiting for internet services to be restored (Halbgewachs et al., 2023; Yang et al., 2023). Other studies report benefits for data analysis, safer aid delivery, and situational awareness, although drone stability, human detection, and communication remain challenges requiring further research (Merkle et al., 2023; Saji et al., 2023; Maghfiroh et al., 2023; Krupakar et al., 2024; Ishiwatari, 2024; Kowshika et al., 2024; Goel & Gupta, 2024). Overall, drones can improve logistical efficiency by accelerating response, restoring communication, assessing damage, and delivering supplies to inaccessible areas. Their integration into Malaysian DROs should account for operational safety, technical limitations, and communication reliability.

The Role of Blockchain Technology in DROs

Blockchain can support disaster management by improving data security, transparency, resource tracking, and coordination. Integrating commercial logistics resources with real-time traffic monitoring, infrastructure maintenance, route planning, and emergency response systems can improve resource mobilization (L'Hermitte & Nair, 2021; Tyagi et al., 2025). These capabilities are relevant to Malaysia, where floods can disrupt transportation and delay the movement of relief supplies. Blockchain also supports resource deployment and decentralized information sharing. These functions can improve communication and joint decision-making among disaster management organizations (Bhat et al., 2021; Bayat et al., 2021). A decentralized application combining blockchain, cloud computing, and the Internet of Things (IoT) can use smart contracts to manage disaster requests and support collaboration (Sreedevi et al., 2021). Several studies have proposed blockchain-based systems for secure data exchange and transparent aid distribution. Blockchain, cloud computing, and IoT can securely record transactions, while other models aim to improve data transmission and protect sensitive information (Sreedevi et al., 2021; Li & Shang, 2022). The Blockchain-based Data Access Ecosystem also addresses data sharing and data quality in systems affected by infrastructure disruptions (Wasserman, 2022).

Further studies have examined blockchain applications in disaster management. These include systems designed to improve transparency, traceability, security, reliability, and collaboration (Kolhatkar et al., 2023; Habib et al., 2025). Prototypes using ReactJS, Web 3.0, Solidity smart contracts, and the Ethereum blockchain have been developed to improve donation transparency and simplify donation processes (Lathkar et al., 2024). Another prototype used mobile and desktop applications to support registration, status updates, and access to relief-related information (Parildar et al., 2023). Other proposed approaches use Hyperledger Fabric and smart contracts for secure information exchange, while machine learning has been applied to storm-severity prediction (Ahmed, 2023; Divya & Samraj, 2024).

Earlier studies proposed federated blockchain networks, digital wallets, and smart contracts to improve connectivity between responders and donors (Badarudin et al., 2020). Decentralized trust-management systems and blockchain-based disaster recovery models have also been proposed to improve trust, record restoration activities, and support dispute resolution (Samir et al., 2019; Demir et al., 2018). Overall, the reviewed studies indicate that blockchain has the potential to improve logistical efficiency through secure recordkeeping, transparent resource distribution, and stronger stakeholder trust. However, the reviewed evidence includes both conceptual frameworks and prototypes, so the findings should not be interpreted as proof that every proposed system has been validated in operational disaster settings (Vaidh et al., 2025).

The Role of Blockchain-Enabled Drones in DROs

Integrating blockchain technology with drones, known as FlyChain in this study, presents a promising method to address communication, coordination, and resource challenges faced by Malaysian disaster response organizations. Drones offer mobility and access to affected areas, while blockchain ensures secure and transparent management of data. This combination enhances information handling and minimizes the risk of

data tampering (Mahmudnia et al., 2022). For logistical coordination, blockchain-enabled drone networks facilitate secure and decentralized information sharing among agencies. RescueChain utilizes a lightweight blockchain structure combined with vehicular fog computing to ensure data integrity and trace resource use during relief efforts (Tychola et al., 2024; Harbi et al., 2023; Wang et al., 2021). Research also explores dynamic data partitioning to improve system interoperability and reduce latency in search and rescue operations. Blockchain-based drone coordination supports collaboration among multiple agencies, enabling more efficient response efforts (Zhang et al., 2025; Hafeez et al., 2024).

Security and multi-agency cooperation benefit from consortium blockchains, which facilitate safe information exchange among participating organizations (Hafeez et al., 2024). To automate drone task management, researchers propose AI-powered tools and smart contracts, while federated learning helps share data securely without compromising privacy (Wang et al., 2025; Chen et al., 2023; Pauu et al., 2024; Alsumayt et al., 2023). Additional security measures include privacy-preserving techniques, hybrid consensus protocols, blockchain-based identity verification, and access control systems, all aimed at restricting drone operations to authorized devices (Pauu et al., 2024; Wang et al., 2023; Dong et al., 2023; Su et al., 2022).

Regarding operational reliability, reinforcement learning assists in optimizing drone flight paths in dynamic environments, while disconnection strategies ensure ongoing task execution when communication links break (Chen et al., 2023; Dong et al., 2023). The TEBChain protocol employs lightweight blockchain methods and signature schemes to maintain data accuracy while reducing communication load by 35 percent (Wang et al., 2024). Techniques such as federated learning, homomorphic encryption, and Internet of Things integration further improve task efficiency and energy conservation (Harbi et al., 2023; Javadpour et al., 2023). Combining 5G technology with blockchain aims to enhance the reliability of medical drones used during emergencies (Chen et al., 2021). Overall, these developments suggest that FlyChain could improve secure data sharing, coordinated drone deployment, and reliable field operations. Nonetheless, its effectiveness in Malaysian disaster scenarios must be validated through practical testing.

Practices to Enhance the Logistical Efficiency of DROs

The analysis identified three main areas for improving logistical efficiency: communication, coordination, and resource management. First, enhancing communication is essential. Drone-based networks can establish temporary connections when traditional infrastructure is unavailable. Aerial mesh networks support mobile phone communication, and combining network coding with blockchain technology improves data transmission and security. Blockchain also facilitates secure information sharing among rescue teams, medical staff, and government agencies (Yang et al., 2023; O'Keeffe et al., 2018; Li & Shang, 2022; Bayat et al., 2021). Second, strengthening coordination involves linking disaster management organizations through decentralized applications, which enable better sharing of information, resource distribution, and joint efforts (Sreedevi et al., 2021).

Blockchain technology can improve data consistency within humanitarian supply chains by using federated networks, smart contracts, and digital wallets to connect responders, suppliers, service providers, and donors (Badarudin et al., 2020). Sharing logistics resources via blockchain streamlines the delivery of relief items and fosters trust between aid providers and recipients (L'Hermitte & Nair, 2021; Samir et al., 2019). Third, optimizing manpower and equipment involves using technology to allocate resources effectively and plan aid delivery. Simulation models, such as HFFPSO, help estimate the number of drones needed for specific areas (Ghelichi & Gentili, 2024; Chandran & Vipin, 2023). Blockchain improves transparency and security in systems managing donations, volunteers, and other resources (Bhat et al., 2021; Kolhatkar et al., 2023). Combining drones with ground vehicles enhances mapping, resource deployment, and response times (Redi et al., 2020).

In summary, the findings highlight drones and blockchain as complementary tools in disaster response logistics. Drones improve access, damage assessment, communication, and delivery, while blockchain increases data security, transparency, and resource tracking. Frameworks such as RescueChain and TEBChain demonstrate methods for ensuring data integrity and coordinating drone activities. Technologies including smart contracts, distributed learning, and route optimization further support reliable operations. These insights underpin the

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development of the FlyChain concept, which requires further evaluation within Malaysian disaster response settings.

Objective 4: Development of an Integrated Framework

This study developed a comprehensive Disaster Relief Operations (DROs) framework by integrating National Security Council (NSC) Directive No. 20, the Sendai Framework for Disaster Risk Reduction (SFDRR), and the Resource-Based View (RBV) Theory. This integration aims to enhance logistical efficiency in DROs. The study aimed to enhance the resilience, adaptability, and effectiveness of DROs in mitigating disaster impacts and saving lives. The goal was to create a framework model applicable to various disaster scenarios globally. This section presents the findings related to Objective 4: Developing an integrated framework of DROs for logistical efficiency. This framework integrates the National Security Council (NSC) Directive No. 20, the Sendai Framework for Disaster Risk Reduction (SFDRR), and the Resource-Based View (RBV) Theory to enhance logistical efficiency in DROs.

This integration guarantees that disaster management practices are responsive, well-coordinated, and adaptable to evolving risks. By aligning with exemplary global practices and national directives, the proposed model strengthens resilience and enhances the capacity of Disaster Response Operations (DROs) to address future crises effectively. This comprehensive framework aims to build resilience and reduce vulnerability to disasters, thereby establishing a more robust disaster relief system in Malaysia and globally. Figure 1, derived from the findings of Research Objectives 1, 2, and 3, visually illustrates this framework. The framework is grounded in the Resource-Based View (RBV) Theory's emphasis on resource optimization, the Sendai Framework for Disaster Risk Reduction's (SFDRR) priorities for action, and the National Security Council (NSC) Directive No. 20's national policy guidelines. This integration ensures that disaster management practices remain responsive, well-coordinated, and adaptive to the dynamic nature of risks. Through alignment with international best practices and national policies, the framework effectively addresses the specific requirements of affected communities while enhancing logistical efficiency. The study contributes to establishing a more resilient disaster relief system, reducing vulnerability, and fostering resilience both within Malaysia and internationally.

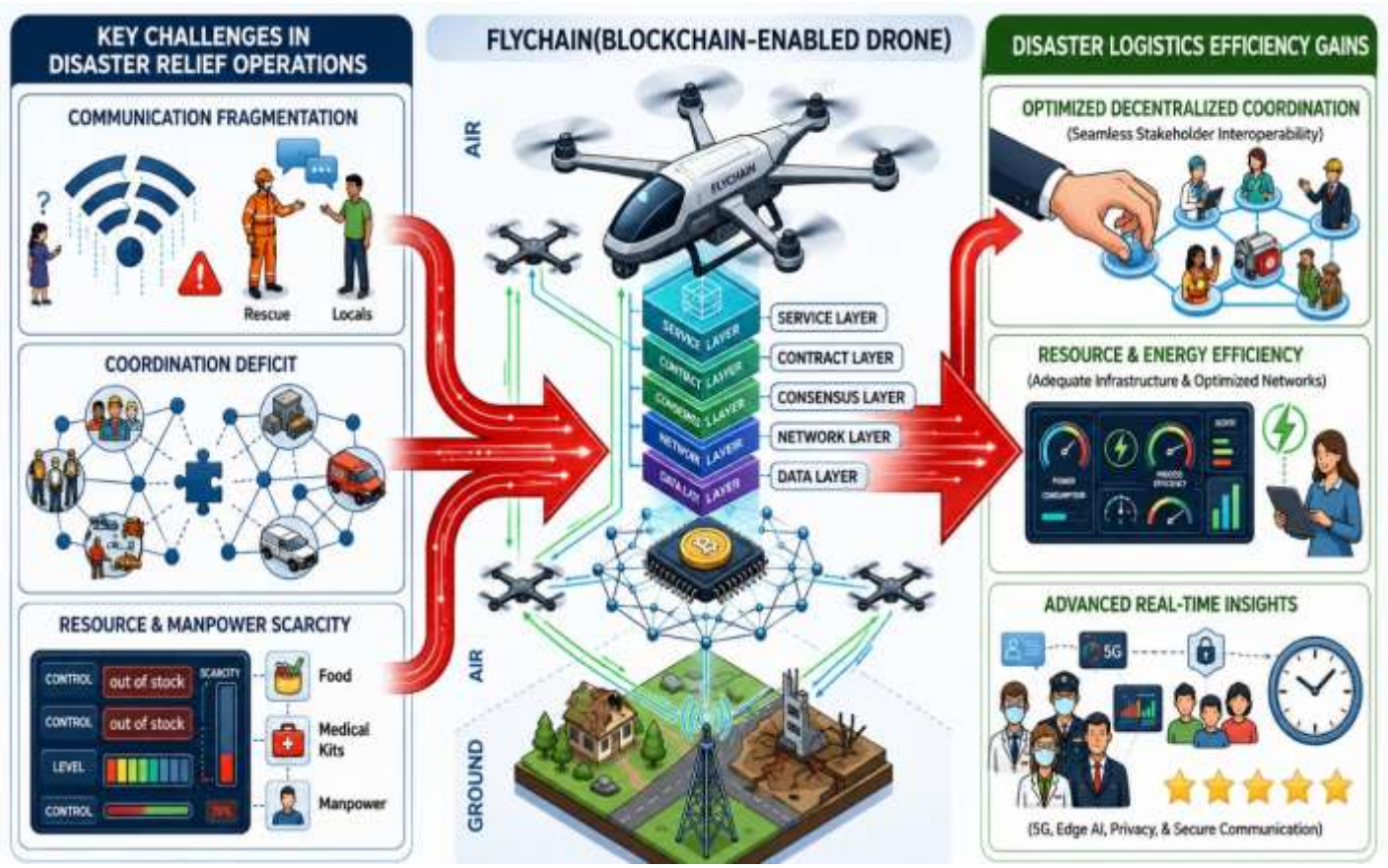


Figure 1: An Integrated Disaster Relief Operations Framework

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DISCUSSION

RQ1: What are the key challenges faced by current DROs in Malaysia?

The findings identified several challenges that hinder the timely and effective delivery of humanitarian aid during Disaster Relief Operations (DROs) in Malaysia. The main challenges involved communication, coordination, and resource limitations, as well as infrastructure gaps, low public awareness, and unpredictable weather.

Communication problems hindered the flow of vital information, impairing decision-making and the delivery of aid. Incomplete or unreliable data, overlapping jurisdictions, and limited knowledge of safe routes delayed response efforts and increased risks for responders and survivors. Muddy roads, physical obstacles, and other hazards complicated route planning, while the lack of local guides for waterways led to incidents such as boat collisions. These issues align with findings by Mabahwi and Nakamura (2020), who examined communication challenges among flood response agencies in Malaysia. Additionally, poor coordination among government agencies at the federal, state, and district levels posed a significant obstacle to effective disaster response. Bureaucratic procedures and strict access restrictions often prevented NGOs and volunteers from entering affected areas. In some cases, authorities seized relief supplies or delayed their delivery while awaiting necessary permissions. These barriers reduced operational flexibility and slowed assistance to communities in need. Muzamil et al. (2022) also identified weak coordination as a key challenge in disaster management.

Weak coordination emerges as a major challenge in disaster management, compounded by resource shortages that hamper operational effectiveness. Limited manpower often forces untrained individuals to perform critical tasks, such as assisting with childbirth aboard boats when medical staff is unavailable. Additionally, a lack of skilled rescuers, insufficient equipment, and delays in rescue operations further hinder response efforts. Difficulties are also exacerbated by inadequate machinery, including the Roll-on Roll-off system, which impedes waste removal, blocks access routes, and slows the movement of supplies. These manpower shortages align with findings by Rosmadi et al. (2023). Infrastructure weaknesses, such as damaged or inadequate evacuation centers, lead to repeated relocations for affected populations. The absence of permanent shelters suitable for prolonged disasters, along with disruptions to electricity and water supplies, complicates relief operations. These issues are supported by Sadeka et al. (2020), who identified shortages of personnel and essential resources as major barriers to effective disaster response.

Other factors also disrupt relief activities. For instance, disaster tourists sometimes interfere with military and NGO personnel by focusing on photography rather than assistance. Limited knowledge of disaster protocols among local authorities hampers the implementation of relief plans. Furthermore, heavy rains during landslide rescue efforts create additional logistical challenges and delay aid delivery. Malaysian disaster response organizations primarily face challenges like communication barriers, poor inter-agency coordination, and shortages of personnel and equipment. Additionally, infrastructure gaps, limited public awareness, and weather challenges hinder their efforts. To improve, it is crucial to develop clearer communication methods, enhance coordination between agencies, and guarantee sufficient staffing and resources. These steps are vital for ensuring faster and more effective disaster responses.

RQ2: How do stakeholders currently address logistical challenges?

The findings indicate that stakeholders in Malaysia have implemented various measures to overcome logistical challenges in disaster relief operations. These measures aim to improve communication, strengthen inter-agency coordination, enhance workforce capacity, and ensure access to essential equipment and technology. Stakeholders emphasized the importance of clear information-sharing through centralized platforms, designated lead agencies, and early warning systems. These efforts seek to provide accurate information to relief agencies and affected communities, reduce misinformation, and prevent response delays. Previous research highlights communication and coordination weaknesses as significant obstacles in Malaysian flood management (Rosmadi et al., 2023; Alias et al., 2018; Wong et al., 2020).

To foster better cooperation, stakeholders have introduced initiatives such as NADMA's Rakan NADMA platform and joint databases for NGOs. These tools facilitate resource sharing, reduce duplication, and improve collaboration among government agencies and non-governmental organizations. Such improvements address concerns about insufficient coordination tools and information sharing identified in earlier studies (Ab Malik et al., 2020; Wong et al., 2020). Additionally, efforts to build workforce capacity include structured training programs and community-based disaster preparedness activities. These initiatives aim to address manpower shortages and enhance community readiness, responding to reports of limited personnel, rescue assets, and public awareness (Rosmadi et al., 2023; Wong et al., 2020; Sadeka et al., 2020; Nazli et al., 2014). Regarding equipment and technology, stakeholders have taken steps to mitigate shortages by deploying machinery in advance, utilizing sensor-based monitoring, and coordinating across sectors to mobilize resources. These measures enable faster deployment and improve response capabilities, addressing issues such as the transport of critically ill patients and delays caused by asset shortages (Maznieda et al., 2022; Yazid et al., 2017).

Moreover, the adoption of information and communication technology, blockchain, and unmanned aerial vehicles has enhanced relief operations. ICT and blockchain improve aid tracking, increase transparency, and reduce duplication, while UAVs provide timely situational assessments and aid delivery in difficult-to-reach or hazardous areas (Ismail et al., 2023). Overall, these efforts have helped address key gaps in communication, coordination, workforce capacity, and equipment. Nevertheless, for these initiatives to be fully effective, they must operate cohesively. Strengthening communication channels and maintaining continuous cooperation among agencies are essential, as is ongoing investment in trained personnel and timely access to resources. These steps are critical for developing a responsive and effective disaster relief framework in Malaysia.

RQ3: What best practices can enhance logistical efficiency?

The findings highlight the importance of advanced technologies in enhancing communication, coordination, and resource management during disaster relief operations (DROs). This approach aligns with the Resource-Based View, which emphasizes leveraging valuable, rare, inimitable, and non-substitutable resources to strengthen operational capacity during disasters (Kwateng et al., 2022). Unmanned Aerial Vehicles support quicker responses through aerial damage assessments, real-time data collection (Krichen & Abdalzaher, 2023), and the delivery of critical supplies, including medical aid, to isolated areas. These technologies help reduce dependence on damaged road networks and address Malaysia's frequent floods and landslides (Abdullah et al., 2022). Blockchain technology can enhance transparency and traceability in aid distribution by creating decentralized, tamper-proof records of relief resources. Such records help reduce fraud and build trust among stakeholders (Sreedevi et al., 2021).

Additionally, blockchain may support coordination by providing a shared record of relief-resource movements, while unmanned aerial vehicles (UAVs) may assist with aerial assessment, communication support, and delivery to selected locations where ground access is disrupted. In this study, the proposed combination of these functions is referred to as FlyChain. Operationally, a future implementation would need to connect drone operators and relevant agency control rooms to an agreed information protocol and a designated logistics coordination function. Each recorded resource movement should use common identifiers and minimum data fields, with role-based access, verification procedures, and an audit trail. Drone missions would require prior assessment of flight safety, weather, payload, battery endurance, landing or handover arrangements, airspace permissions, and the availability of trained operators. Because floods may damage power and telecommunications infrastructure, the system should also provide offline or store-and-forward procedures and a manual fallback process. These are proposed design requirements, not capabilities demonstrated by the present study. FlyChain's operational performance and its contribution to logistical efficiency remain to be tested in Malaysian disaster settings.

RQ4: How should an integrated framework be developed?

The study proposes an integrated Disaster Relief Operations (DRO) framework that combines the Sendai Framework for Disaster Risk Reduction (SFDRR), the Resource-Based View (RBV) theory, and National Security Council (NSC) Directive No. 20. The framework aims to enhance logistical efficiency and improve disaster response in Malaysia by connecting international disaster risk reduction priorities, organizational

resources, and national disaster management policies. The SFDRR outlines key priorities such as understanding disaster risk, strengthening disaster-risk governance, investing in risk-reduction measures, and preparing effectively for emergencies. These priorities were adapted to the Malaysian context to inform disaster planning and response strategies. The RBV emphasizes the importance of effectively utilizing organizational resources and capabilities.

In this framework, FlyChain is a proposed system that combines blockchain-supported resource tracking and information sharing with drone-based assessment, communication support, and possible last-mile delivery. Its operational integration would require an agreed governance structure linking NADMA and relevant federal, state, and district agencies, as well as participating NGOs and logistics providers. Before deployment, stakeholders would need to define who can enter, verify, access, and correct records; establish shared data standards and procedures for incident updates; and identify which decisions remain under the designated incident commander's authority. Drone operations would be planned according to assessed needs and site conditions, with conventional transport retained as the default where it is safer or more practical. The framework should also include contingency procedures for damaged communications, power shortages, adverse weather, unsafe landing areas, and unavailable equipment. These operational elements are proposed for future design and evaluation; they were not implemented or validated through this qualitative study. The integration of FlyChain into NSC Directive No. 20 arrangements would therefore require consultation with the responsible agencies and an assessment of legal, data protection, procurement, and operational requirements.

CONCLUSION

This study examined how an integrated Disaster Relief Operations framework could address logistical challenges in Malaysia. Based on interviews with 13 informants, observations in Kelantan and Pahang, and document analysis, the study identified three interconnected challenges: fragmented coordination, communication failures, and manpower and equipment shortages. Stakeholders described approaches that included inter-agency communication, partnerships, community preparedness, resource mobilization, and early warning systems. Drawing on these findings, the study proposes a framework that connects the Resource-Based View, the Sendai Framework for Disaster Risk Reduction, and National Security Council Directive No. 20. It also introduces FlyChain as a combination of blockchain-supported resource tracking, drone-enabled assessment, communication support, and potential supply delivery. The contribution is the development of an evidence-informed framework that links governance, organizational resources, and possible technological support. The study does not demonstrate that FlyChain reduces response times, increases successful deliveries, improves transparency, or lowers costs. It should not be interpreted as a validated or deployment-ready system. Its feasibility, affordability, reliability, and scalability remain open questions that require staged evaluation before any decision on broader implementation.

Limitations

This study has several limitations. First, it used a qualitative design with 13 informants and focused on Kelantan and Pahang in Peninsular Malaysia. Although participants represented several stakeholder groups, the sample did not cover all administrative levels or all regions exposed to disasters; the findings are therefore context-specific and should not be generalized to the whole country without further study. Second, interviews, observations, and thematic analysis involved researcher interpretation, which may have influenced the categorization of findings. Third, the study developed a conceptual framework but did not build, simulate, or pilot-test FlyChain. It therefore provides no measured evidence on system reliability, response times, delivery success, resource traceability, operating costs, maintenance requirements, user acceptance, or performance under damaged infrastructure and intermittent connectivity. Fourth, the study did not conduct a formal technical feasibility assessment or cost-benefit analysis. Practical questions remain about procurement and replacement of drones and network equipment, staff training, software and ledger maintenance, cybersecurity, battery and power availability, connectivity, data governance, insurance, and compliance with relevant opera-

ting requirements. These costs and requirements could be substantial in resource-constrained settings and should be assessed rather than assumed to be manageable. Finally, disaster statistics and other secondary information should be checked against their original sources before publication. These limitations mean that the proposed

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framework is a qualitative, evidence-informed design proposal, not empirical proof of the effectiveness or scalability of FlyChain.

Future research

Future research should proceed in stages rather than move directly to nationwide implementation. First, conduct co-design workshops with NADMA and relevant federal, state, and district agencies, NGOs, drone operators, logistics providers, and affected communities to specify operational responsibilities, data-sharing rules, procurement needs, and deployment criteria. Second, undertake a technical and financial feasibility study to estimate initial procurement costs and recurring expenditures for training, software support, cybersecurity, connectivity, battery replacement, repairs, insurance, and system maintenance. The assessment should compare FlyChain with existing communication and logistics procedures and identify conditions under which conventional methods remain preferable. Third, develop and test a limited prototype in a controlled exercise before considering a small, supervised pilot in a suitable flood-prone location. The pilot should include contingency procedures for network failure, power loss, adverse weather, inaccessible landing areas, and drone unavailability. Evaluation measures should be defined in advance and may include time to share verified information, inventory record accuracy, delivery completion rate, time from request to delivery, cost per successful delivery, system uptime, safety incidents, and user acceptance. Baseline or comparison data should be collected so that any claimed improvement can be assessed rather than presumed. Only after technical, operational, ethical, and financial results support the case should expansion to other Malaysian states or ASEAN settings be considered.

FlyChain may warrant further consideration in Malaysia and other disaster-prone countries, but its potential benefits should be distinguished from demonstrated outcomes. In Malaysia, drones could be assessed for specific tasks, such as delivering lightweight medical supplies to remote locations or collecting aerial data where access is unsafe. Blockchain could be assessed for maintaining auditable records of resource requests, dispatches, transfers, and receipt. A pilot should test whether these functions offer benefits beyond those of existing databases and communication systems, particularly when connectivity is intermittent. Cross-country transfer should be considered only after local testing, because governance arrangements, airspace rules, infrastructure, procurement capacity, and disaster conditions differ. Pilot findings should inform decisions about whether to retain, modify, or discontinue the proposed system.

Malaysia should also strengthen disaster risk reduction through infrastructure planning and policy implementation. Any revision of NSC Directive No. 20 or related procedures should be informed by consultation with responsible agencies and clarify operational coordination, information-sharing responsibilities, and resource accountability arrangements. Sensor networks and data-driven risk mapping may support flood and landslide monitoring, enabling agencies to maintain equipment and use the resulting information. Public-private partnerships could help mobilize logistics capacity, but their arrangements should specify responsibilities, costs, data access, service expectations, and accountability. These measures should be assessed against local needs and available resources before being adopted at scale.

Community preparedness should remain a core component of disaster risk reduction. Community-Based Disaster Risk Management programs can train local volunteers in preparedness, first aid, safe reporting, and communication with authorized response agencies. If FlyChain is piloted, community members should receive clear guidance on the technology's limited role, how to report information safely, and how personal or sensitive data will be handled. Community exercises should connect local knowledge with official response procedures while avoiding the assumption that volunteers can replace trained emergency personnel. Evaluation should examine whether these activities improve preparedness and coordination and whether the responsibilities placed on volunteers are appropriate. Overall, the recommendations prioritize stakeholder co-design, feasibility assessment, controlled testing, and community preparedness before any wider implementation of FlyChain.

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