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MANAGEMENT (JISTM)**www.jistm.com**IMPACT OF TECHNOLOGY IN HUMANITARIAN ASSISTANCE
AND DISASTER RELIEF OPERATION TOWARDS
ASSOCIATION OF SOUTHEAST ASIAN NATIONS**Surenthiran Krishnan¹, Norhazlina Fairuz Musa Kutty^{2*}¹ Defence Cyber and Electromagnetics Operations Headquarters, Malaysian Armed Forces, Malaysia
Email: surenthiran@mod.gov.my² Head of Department, Department of Defence and Strategic Studies, Faculty of Defence Management Studies,
National Defence University of Malaysia.

Email: nfairuz@upnm.edu.my

* Corresponding Author

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This work is licensed under [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/)**Abstract:**

This study examines the transformative role of emerging technologies in enhancing Humanitarian Assistance and Disaster Relief (HADR) operations across the ASEAN region. The need for rapid, coordinated and data-driven responses is critical due to ASEAN's vulnerability to natural disasters. This paper evaluates the technological readiness and integration within ASEAN's disaster management ecosystem, using the Sendai Framework for Disaster Risk Reduction (DRR) as a guiding structure. A qualitative research approach was employed, involving expert interviews with stakeholders from eight ASEAN nations and relevant agencies, including NADMA and MMEA. The findings highlight a growing demand for technology attributes such as interoperability, real-time data acquisition, geospatial intelligence, autonomous systems and resilient communication networks. Technologies such as artificial intelligence (AI), drones, Internet of Things (IoT), and blockchain are identified as enablers for enhanced situational awareness and effective resource coordination. Despite their potential, challenges persist in infrastructure limitations, fragmented data systems, cybersecurity vulnerabilities and funding constraints. Therefore, the paper proposes a Hybrid Technology Framework aligned with the four priorities of the Sendai Framework. The model leverages the DIKW Model to integrate big data analytics with operational decision-making in HADR contexts. The proposed framework is proven to improve the efficiency, scalability and resilience of ASEAN's disaster response mechanisms. The ASEAN HADR operations must embrace IR4.0 technologies to shift from reactive to proactive disaster management. This transition will not only bridge existing capability gaps but also promote regional cooperation, enhance institutional capacity and foster community-based resilience.

Keywords:

Humanitarian Assistance, Disaster Relief, ASEAN, Technology Integration, Sendai Framework, Situational Awareness, Interoperability

Introduction

Natural disasters are major threats to life and infrastructure, especially in developing nations with weak disaster management. The Association of Southeast Asian Nations (ASEAN) often experiences floods, landslides, earthquakes, and tsunamis. The 2004 Indian Ocean tsunami was the deadliest, with about 200,000 fatalities in the region. (Braman, 2014; Gentner, H. H., 2006), Typhoon Haiyan (Yolanda) in 2013, eruption of Mount Merapi in 2010 (Terms, 2014; Trias & Cook, 2021). Therefore, those stakeholders in ASEAN have to take part in the operations of HADR to deal with these catastrophes (Cook & Chen, 2022; Hughes, 2015).

The ASEAN Agreement on Disaster Management and Emergency Response (AADMER) enhances regional cooperation in disaster management, including HADR operations. These operations play a crucial role in supporting ASEAN member states during emergencies. (Nguyen Thi Thuy Ha, 2013). Besides that, ASEAN has demonstrated the extensive network of emergency includes the disaster responders in natural hazards, conflicts and the COVID-19 pandemic. Militaries play a crucial role in this network due to their distinctive resources and expertise. However, research on how these military forces connect and interact with one another and with other stakeholders in Southeast Asia is limited. So, lacking of technology attributes and data coordination is one of the critical issues in HADR operation in ASEAN (Trias & Cook, 2021). There is the limitations in the use of technology and standardized procedures in disaster preparedness and response during the HADR operation (Spandler, 2022).

Technological advancements play a critical role in improving the efficiency, coordination and effectiveness of disaster response efforts. Technology facilitates the development and operation of early warning systems that provide timely alerts for HADR operation. The technology in HADR operation demand sensors, satellite imagery, meteorological data and communication technologies to monitor and detect potential disasters (Khalifeh et al., 2022). This allows the early evacuation and preparedness during the HADR operation (Kumsap et al., 2018).

Type of HADR

In the ASEAN region, HADR operations encompass a wide range of activities aimed at aiding and relief to communities affected by natural disasters, emergencies and humanitarian crises. ASEAN countries frequently experience natural disasters such as typhoons, earthquakes, floods, landslides and tsunamis. HADR operations involve emergency assistance, search and rescue operations, medical aid, shelter, food, clean water and essential supplies to affected communities as shown in Table 1.

Table 1: Criteria and Aim of HADR

Criteria	Focus	Aim
Preparedness & Risk Assessment	Planning, mitigation, reduction and logistics, and risk	Minimize disaster impact and improve resilience
Humanitarian Assistance	Support for displaced people, refugees, and IDPs	Provide food, medical aid, shelter, transport, and coordination
Pandemic Response	Healthcare needs, SOPs, and emergencies	Supply medical aid and strengthen health systems
Environmental Disasters & Climate Change	Response to environmental and climate-related events	Clean-up, restore ecosystems, and reduce climate impacts
Cross-Border Cooperation	Regional coordination via AHA Centre	Share resources, expertise, and information for better HADR
Data Integration	Merging data from various sources	Enable efficient data sharing and situational awareness
Emerging Technology	Use of new technologies in HADR	Enhance real-time data, decision-making, early warning, and situational awareness

HADR efforts in ASEAN focus on disaster and risk assessment, preparedness, mitigation and risk reduction initiatives. This includes capacity-building activities, training programs, community-based disaster preparedness campaigns and the development of early warning systems to minimize the impact of disasters and enhance resilience. Technology is seen as the one of the major entities that will binds all the criteria and escalate the effectiveness of HADR in ASEAN (Mukherjee et al., 2023).

Situational Awareness in HADR

Advanced technologies such as Geographic Information Systems (GIS), remote sensing and unmanned aerial vehicles (UAVs) provide valuable insights and situational awareness to responders by delivering high-resolution imagery, maps and data on disaster-affected areas (Hildmann & Kovacs, 2019). This enables more informed decision-making, resource allocation and prioritization of response efforts and an enhanced situational awareness (Erdelj et al., 2017). UAVs and thermal imaging cameras enhance search and rescue operations by providing aerial reconnaissance and aid in identifying survivors in remote or inaccessible areas. These will guide response teams to their locations more quickly and efficiently (Hildmann & Kovacs, 2019). The response time of disaster management personnel during a natural disaster is key in saving the lives of those in the affected areas. The most efficient situational awareness is achieved through UAV networks (Erdelj et al., 2017).

Early Warning System in HADR

Technology plays a crucial role in the development and operation of early warning systems for natural disasters such as tsunamis, earthquakes, hurricanes and floods. These systems utilize sensors and satellite imagery to provide the description of the disasters' state. The data analytics will aid to detect and forecast impending disasters, allowing for timely evacuation and risk assessment (Sun et al., 2020).

Artificial Intelligence in HADR

Artificial intelligence (AI) refers to the human-created intelligence developed in machines and computers to think and act like humans. It can learn data patterns, analyse information and solve problems in a manner similar to the human brain (Krishnan et al., 2021). Big data with AI help to analyse large volumes of data generated during disasters in identifying behaviour patterns and foresight emerging risks. This enables responders to make data-driven decisions to develop their plans in disasters. Besides that, this will allocate resources more effectively to address priority areas (Sun et al., 2020). It is plausible that the use of military will enhance the connectivity and increase efficiency in HADR operations. There are broadly two areas military forces that battle proven in Sri Lanka in the use of AI to enhance their HADR operations. The areas are logistics and ISR (intelligence, surveillance and reconnaissance) operations using UAVs (Meegoda, 2018).

Technology Issues for HADR Operation In ASEAN

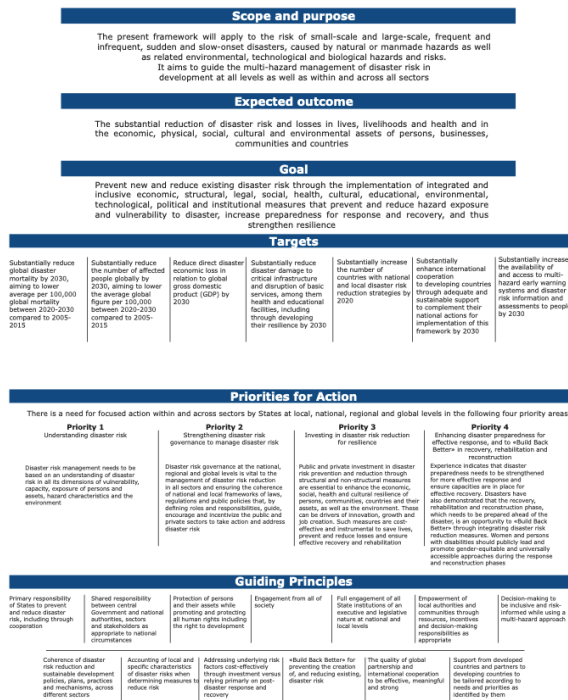
Technology plays a crucial role in enhancing the effectiveness and efficiency of HADR efforts. There is a need for advanced early warning systems that utilize technologies such as sensors, satellite imagery and data analytics to detect and predict natural disasters.

Demand for Technology

The use of technology in disaster preparedness is very demanding to ensure the effectiveness of HADR operations (Spandler, 2022). The needs of technology attributes in HADR operations within the ASEAN region is significant due to the region's vulnerability to natural disasters such as earthquakes, storms, typhoons, floods, drought and tsunamis. Storms and flood seem to one of the most critical and affected the ASEAN countries the most especially Philippines and Indonesia (Avila & Matthews, 2022; Cook et al., 2019).

Sendai Framework

The Sendai Framework for DRR 2015-2030 as shown in Figure 1 has seven targets and four priorities for action to mitigate the disaster risks. This international framework is adopted at the Third United Nations World Conference on DRR in Sendai, Japan. First it focuses in understanding the disaster risk and strengthening disaster risk governance to manage disaster risk. It will propose and guide in investing for disaster reduction's resilience. Besides that, enhancing the disaster preparedness towards "Build Back Better" in recovery, rehabilitation and reconstruction is one of the main concerns. It aims to achieve the substantial reduction of disaster risk and losses in lives in the economic, physical, social, cultural and environmental assets globally over the next 15 years. This framework was adopted at the Third UN World Conference on Disaster Risk Reduction in Sendai, Japan, on March 18, 2015 (Busayo et al., 2020; Pearson & Pelling, 2015).

**Chart of the Sendai Framework for Disaster Risk Reduction
2015-2030****Figure 1: Sendai Framework for Disaster Risk Reduction 2015-2030 (Pearson & Pelling, 2015)*****Demand on Technology in HADR Framework***

The demand for advanced technology attributes in HADR operations has surged by the need for rapid, efficient and effective response capabilities. Technologies such as UAVs, AI, real-time data analytics and satellite communications are increasingly vital for situational awareness and decision-making in disaster-stricken areas. This research highlights on the demand for technology attributes in HADR as shown in Table 2.

Table 2: Demand for Technology in HADR

Author	Findings	Drawbacks
(Idris & Che Soh, 2014)	Human resource, communication and information technology are crucial to carry HADR.	Need for technology domain that comprises all important aspects in HADR in ASEAN countries.
(Upadhyaya, 2022)	Data coordination is one of the factor that delay most of the HADR operations.	Need data coordination with an efficient communication in HADR.
(Canyon et al., 2020)	Decision making could not be made due to the lack of real time data from the disaster areas.	Situational awareness is crucial for effective HADR operations. Responders to act swiftly, efficiently and safely to mitigate the impacts of disasters.
(Mukherjee et al., 2023)	Situational Awareness can slow down the effectiveness	Lack of data integration and coordination timely
(Jayasekara et al., 2023)	Communication and data sharing are crucial in HADR op	Lagging in data transfer and ineffective communication

The importance of situational awareness is seen as the major factor that could enhance the overall HADR operations. This allows the commanders, leaders in the command centre of HADR to understand the status of the disaster area, including geographical, meteorological and socio-political conditions. HADR team able to conduct their planning for resource allocation, risk assessments and deployments of troop by identifying the most affected areas (Wei et al., 2024). A comprehensive data and real updates on the disaster areas will help in identifying potential hazards and risks. This will benefit the responders to take preventive measures to protect both themselves and the affected population. In overall, this will minimise the impact of the disaster and enhance the effective of HADR (Nyuyen Thanh Trung, 2020).

UAVs provide critical aerial assessments while AI enhances predictive modelling and resource allocation. In fact, the real-time data analytics offer up-to-date information for better coordination and satellite communications ensure connectivity in remote or infrastructure-damaged regions. These technological advancements enable HADR operations to be more responsive, adaptive and impactful in mitigating the effects of disasters and providing timely aid to affected populations.

Issues of Technology in HADR

Qualitative approach is used by conducting an interview. The interviews that have been conducted with 10 respondents, 8 ASEAN countries experts from Singapore, Indonesia, Philippines, Thailand, Cambodia, Brunei, Malaysia and 2 experts from NADMA and Malaysia Maritime Enforcement Agency (MMEA). Consequently, the qualitative approach and interview questions have produced an insight of the technology demands in HADR and the establishment attributes. Many ASEAN countries are facing infrastructure limitations on technology deployments such as inadequate telecommunications and limited access to electricity. These challenges can hinder the deployment and operation of advanced technologies during HADR missions as shown in Figure 2.

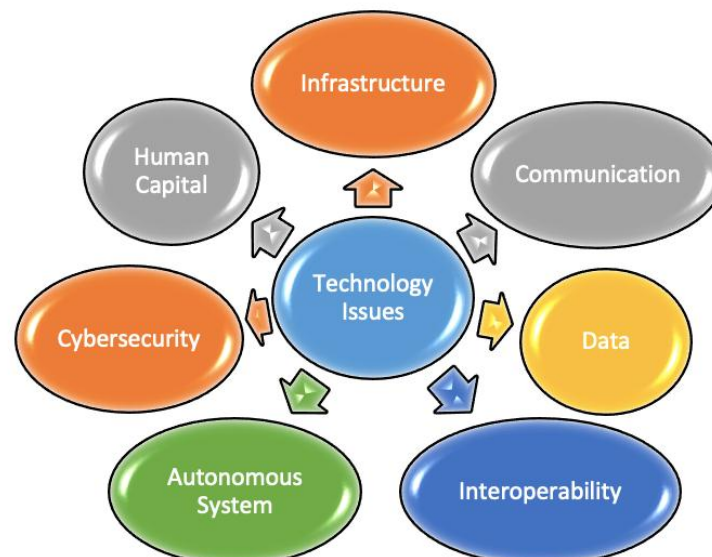


Figure 2: Critical Technology's Issues in HADR

Disasters often disrupt communication networks, making it hard for HADR operations to coordinate effectively. A resilient communication system is vital to maintain connectivity during emergencies. Data in HADR is complex and scattered across multiple agencies, including the military. Accurate, timely data and system interoperability are crucial for better

decision-making and situational awareness. (Pradhan, 2019). Interoperability between different platforms and equipment in HADR operation is another critical issue. Integration of data and platforms synchronization are essential to achieve compliance, but they become one of the challenges that lead to inefficiencies during HADR efforts. This strictly shows the need for standardized communication protocols and compatible technologies. Most of the disaster-affected areas in ASEAN countries are remote and difficult to access. Therefore, autonomous system would save the time and access to any extent in the disaster areas. These systems are able to send precise and accurate data in real time to assist decision making and update the situational awareness (Erdelj et al., 2017). Cybersecurity threats become more prevalent proportionally with the rising of technology use in HADR operations. Critical infrastructure become the target to exploit vulnerabilities in digital systems. The reason is to disrupt the response efforts and compromising sensitive data. Many ASEAN countries may lack the technical expertise and capacity to effectively utilize advanced technologies for HADR. So, training and creating awareness on cyber security are to defend the infrastructure and data during disasters (Ikeda & Silapunt, 2022).

Evaluation on HADR Requirements

This HADR evaluation aims to enhance the disaster response in the ASEAN region. It identifies the specific needs based on past disaster data and future risks. A technology audit able to review and revise the current HADR technologies, its relevance and potential improvements. In other hand, testing and simulations will evaluate their performance in realistic scenarios. The continuous feedback loop ensures the ongoing improvement through regular reviews and enhancement. Finally, interoperability ensures seamless communication and data exchange across different HADR systems through standardized protocols. The identified tenets related for technology attributes in HADR assessment are coordination, technology audit, testing and simulations, feedback loop and interoperability. The evaluation will be done using on the existing HADR framework as per shown in Table 3.

Table 3: Discussion on Key Technology Attributes in HADR

Attributes	Purpose	Deduction
Interoperability	The ability of different systems, organizations and countries to work together seamlessly (Aretoulaki et al., 2023)	Ensures that technologies used by different ASEAN member states can communicate and operate in conjunction with each others.
Scalability	The capacity of technology to handle increasing amounts of work (Gray & Colling, 2021)	Critical for scaling operations during large-scale disasters, ensuring that systems can handle peak loads
Reliability and Resilience	The dependability of technology to function under stress and adverse conditions (Benekos et al., 2022; Xu et al., 2021)	In disaster scenarios, technology must remain operational despite infrastructure damage and other challenges
Ease of Deployment	The simplicity with which technology can be set up and operated (Rameshwar Dubey Angappa Gunasekaran & Papadopoulos, 2020)	Technologies should be easy to deploy and use by non-experts, including local volunteers and international teams unfamiliar with the region.

Cost-effectiveness	The efficiency of technology in terms of cost relative to its benefits (Kumar & Singh, 2022).	Budgets for HADR operations are often limited. So, cost-effective solutions are necessary to maximize resource utilization
Adaptability and Flexibility	Adapted and flexible for various situations (Dashtpeyma & Ghodsi, 2022)	Technologies should be versatile to address different types of disasters and changing operational needs
Real-time Information Sharing	The precision of data and the capability to share it instantly (Elmhadhbi et al., 2021)	Accurate, real-time data is crucial for effective decision-making and coordination in disaster response
Sustainability and Environmental Impact	The environmental footprint of technology and its long-term viability (Shakibaei et al., 2024)	Technologies should be sustainable and have minimal adverse environmental impacts, especially in fragile ecosystems
Cultural and Social Acceptance	To be accepted and embraced by local communities (Elbyaly & Elfeky, 2023)	Technology must be culturally appropriate and accepted by the local population to be effectively utilized.
Security and Privacy	Protect data and systems from unauthorized access and ensure privacy	Protecting sensitive information and ensuring the security of communication systems is crucial in HADR operations.

Evaluation On Sendai Framework

This framework main concern is to significantly reduce disaster risk and losses in livelihoods and health (Mizutori, 2020). It provides guidance for both disaster risk reduction and effective disaster response, emphasizing a proactive, preventative approach rather than merely reactive measures. Based on the Table 4, the guiding principles from Sendai Framework can be evaluated as comprehensive. The DRR is the responsibility of each state, in this context it refers to ASEAN, which are supported by cooperation with relevant stakeholders that only can be merged with the presence of good technology.

Table 4: Priorities of Sendai Framework (Pearson & Pelling, 2015)

Priority	Components	Areas	Purpose	Deduction
1. Understanding Disaster Risk	Risk Knowledge, Information Systems	Understand risk factors: vulnerability, exposure, environment	Provide risk maps and data to decision-makers, the public, and at-risk communities	Improve awareness and enable better decision-making
2. Strengthening Disaster Risk Governance	Policies, Legal Frameworks, Institutions	Develop and coordinate DRR strategies across sectors	Create strong national/local platforms to promote coordination among stakeholders	Promote collaboration among governments and sectors

Priority	Components	Areas	Purpose	Deduction
3. Investing in DRR for Resilience	Public & Private Investment, Sustainable Development	Promote investments in risk prevention (structural & non-structural)	Include DRR in development programs, poverty reduction, and sustainability goals	Build long-term resilience and reduce future disaster impact
4. Enhancing Preparedness and Building Back Better	Preparedness Plans, Recovery Strategies	Ensure coordinated disaster response and recovery	Integrate DRR in post-disaster recovery to improve resilience for future disasters	Strengthen recovery and prepare better for future disasters

Eventually, Sendai Framework encourage the international cooperation and partnerships. This will strengthen up the international cooperation and forming partnerships with various stakeholders to share their knowledge, technology and resources. The Sendai Framework shows the needs of technology respective in its 4 priorities as shown in Figure 3. For Priority 1, the understanding of disaster risk needs the consideration of the policies and practices for disaster risk management. It needs to collect all related information on disaster risk in all its dimensions of vulnerability, capacity hazard characteristics and the environment. These will provide a better understanding and insights that can be leveraged for the purpose of pre-disaster risk assessment. This will assist the development of appropriate preparedness and effective response to disasters. So, technology attributes that capable to collect all data is very crucial in HADR operational centre to make the leaders to achieve the Priority 1.

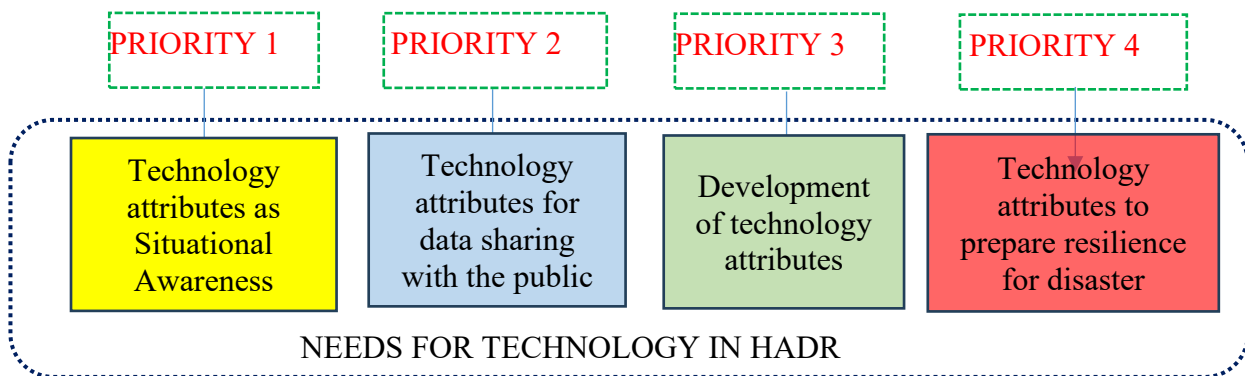


Figure 3: Gaps in Sendai Framework

For Priority 2, the main concern is to enhance the management of disaster risk by improving and strengthening disaster risk governance at the local, national, regional and global levels. In the context of policy and legal frameworks, a comprehensive policies, laws and regulations need to be designed to guide DRR efforts. These frameworks should be inclusive and account for all stakeholders, including vulnerable and marginalized groups. Besides that, establish clear and robust coordination mechanisms across different sectors and levels of government to ensure cohesive and effective DRR strategies.

Main objective of Priority 3 is to reduce disaster risk through dedicated investments in DRR and resilience-building activities. This will minimize the economic, physical, social and environmental impacts of disasters. It promotes the investments in resilient infrastructure and essential services by ensuring they can withstand and recover from disasters. Priority 4 focuses in enhancing disaster preparedness and to ensure the effective response. It promotes the principle of "Build Back Better" in post-disaster by implementing the recovery, rehabilitation and reconstruction. Gap Analysis in technology attributes for HADR is shown in Table 5.

Table 5: Gap Analysis in Technology Attributes for HADR

Technology Attributes	Gap Analysis	Action Plan
Seamless communication	Legacy communication system are facing interoperability issues.	Integration under single platform.
Situational awareness	Lack of sensors to collect data from the HADR areas in real time.	Integrate and install sensors and optimise the use of IOT.
Interoperability	Variations and generations of technology gadgets facing interoperability issues.	Integrate, test and evaluate its performance to collect and analysis data.
Geospatial mapping	Lack of devices for remote sensing and mapping on the HADR areas.	Purchase and integrate with existing platforms.
Real-time data visualization	Delay of data transfer. Even near to real time have latency.	Enhance the data transfer and connectivity with satellite.
Rapid response	Delay on deployment due to lack of planning and information on the disaster areas.	Enhance situational awareness in real time.
Autonomous System	Lack of latest autonomous system such as UAV, UGV and UUV.	Autonomous is crucial to conduct operation 24/7 and access to high risk areas.
Data sharing and data quality	Variety of platforms and format to collect and store data.	Use of big data to collect continuously on all sensors.
Data coordination	Lack of command, control, communication from top to down in HADR theatre.	Situational awareness for decision making.

Primarily the financial become the main issue to implement the technology in HADR. Technologies are available widely where it needs infrastructure, technological expertise and tuning of the emerging technologies. So, this research discusses the main reason of technology setbacks in ASEAN countries as shown in Table 6.

Table 6: Analysis on Technology Setbacks in HADR

Factor	Analysis	Deduction
Limited Financial Resources	Funding is often prioritized for immediate relief and recovery efforts rather than maintaining equipment and systems.	Limit their ability to invest in advanced technologies.

Infrastructure Challenges	Inadequate infrastructure impede the effective deployment of technology in disaster response.	Poor infrastructure in rural and remote areas complicates the implementation of technology.
Technological Readiness and Expertise	Lack the technical expertise and skilled personnel to operate and maintain advanced HADR technologies.	Training is essential to ensure that responders can effectively use new technologies.
Access to Cutting-edge Technology	Acquiring the latest technology due to high costs, trade restrictions and competition.	Should plan wisely to gain all latest technology.
Coordination and Information Sharing	Inconsistent data standards and a lack of interoperable systems can hinder the integration of technology.	Effective HADR operations require seamless coordination and information sharing.

Technology Impact of Sendai Framework in ASEAN HADR

The Sendai Framework has significantly enhanced HADR operations in ASEAN by fostering stronger regional cooperation, building institutional capacities and integrating DRR into development policies. ASEAN Agreement on Disaster Management and Emergency Response (AADMER) and the ASEAN Coordinating Centre for Humanitarian Assistance (AHA Centre) are two main initiatives that have promoted standardized procedures and a community-based disaster management. Besides that, to achieve those priorities in Sendai Framework, there is a crucial demand for investment in resilient infrastructure especially in technology. These efforts have improved early warning systems, public awareness and overall preparedness.

The impact of Sendai Framework has been very significant with the HADR operations in ASEAN and has been shown in Figure 4. Most of the ASEAN countries have implemented this model effectively during the recent disaster and their preparedness for HADR. Primarily, the Sendai Framework able to enhance the policy and institutional HADR in ASEAN by regional cooperation. The Sendai Framework has encouraged ASEAN member states to strengthen regional cooperation on DRR. This has led to the development of collective policies and institutional frameworks to enhance disaster preparedness and response. For an example the AADMER highlights the principles of the Sendai Framework and serves as a comprehensive regional policy for HADR. It emphasizes risk reduction, preparedness and effective response strategies.

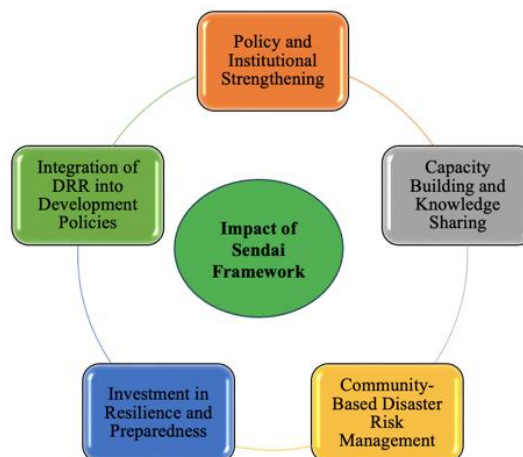


Figure 4: Impact of Sendai Framework (Krishnan S, 2024)

Subsequently, the Sendai Framework has assisted the capacity building and knowledge sharing among ASEAN countries. AHA Centre has been instrumental in implementing the Sendai Framework by facilitating capacity-building programs, training and knowledge-sharing initiatives among ASEAN member states. The AHA Centre has developed and standardized SOPs for disaster response. It ensures a coordinated and efficient approach to HADR across the region. Thirdly, the Sendai Framework promotes Community-Based Disaster Risk Management (CBDRM) which has been adopted by many ASEAN countries. This approach involves local communities in planning and implementing DRR activities to ensure the efforts with the specific local needs and conditions. Apart of that, it also focuses on education and creating awareness by providing public education and awareness campaigns (Pearson & Pelling, 2015).

Fourthly, ASEAN countries have invested in resilient infrastructure and advanced technology to improve its preparedness and response capabilities. For example, early warning systems and resilient public infrastructure have been developed in line with Sendai Framework recommendations. It has encouraged the establishment of financial mechanisms, such as disaster funds and insurance schemes, to support recovery and reconstruction efforts (Mizutori, 2020). Fifthly, the Sendai Framework's emphasis on integrating DRR into development policies. This has influenced ASEAN countries to incorporate risk reduction strategies into their national development plans. This holistic approach ensures that development efforts contribute to reduce the vulnerabilities and enhancing resilience. DRR considerations have been integrated into urban planning to lead a safer and more resilient cities (Busayo et al., 2020). Therefore, the deductions and demands technology attributes are plotted to meet and comply the gaps with the Sendai Framework Priorities as shown in Figure 5.

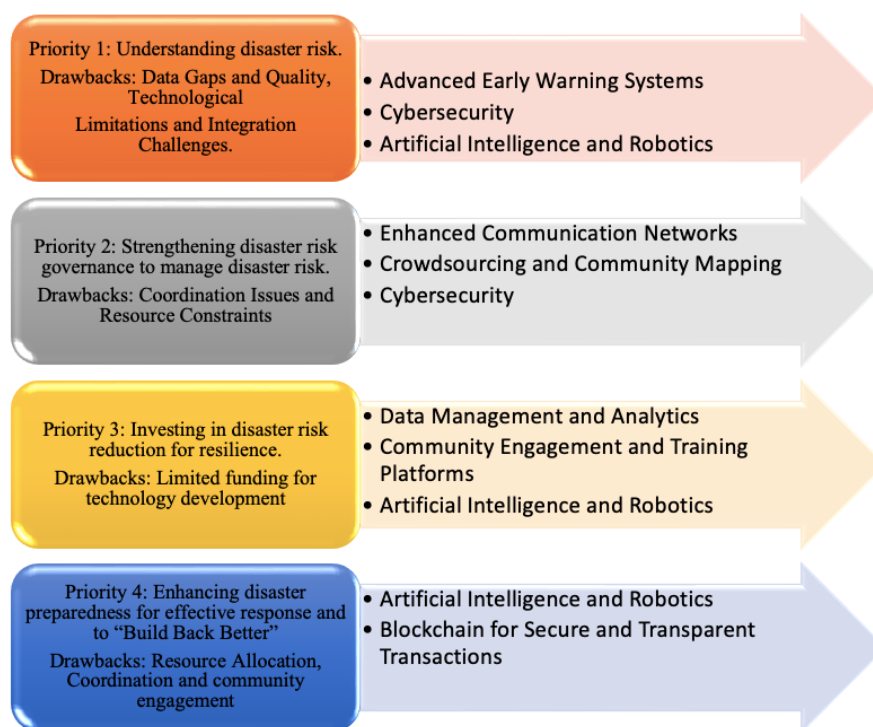


Figure 5: Technology Attributes Enhancement in Sendai Model (Krishnan S, 2024)

Technology Impact in Efficiency for HADR Op In ASEAN

The integration of technologies into HADR operations have the potential to revolutionise the disaster management in ASEAN which are prone to a variety of natural disasters (Aretoulaki et al., 2023). A comprehensive conceptual framework is essential to systematically understand and elaborate on the impact of technology in HADR.

Proposed Hybrid Framework of Technology Impact in HADR

This framework can be divided into several key components of technology streamline such as information gatherings, data processing and results. It consists of 4 main data analytics (Krishnan et al., 2021) in technology which contribute on the impact of HADR in each stages of disasters. Pre-disaster focuses on data gathering using descriptive analytics that provide the situational awareness based on the collected data from sensors, drones and responders from the field. The collected information is processed and be part of diagnostics analytics to provide for the real-time response. Just before a disaster occurs, it will trigger the predictive analytics to predict the intensity of disaster based on the behaviour pattern and history from the collected information. Subsequently, it will generate an early warning to alert public on the disasters. Immediately, the prescriptive analytics will propose a few feasible and suitable action plan with the minimum risks on the disaster areas.

Blockchain provides transparent and immutable records of aid distribution by ensuring accountability and reducing corruption. It improves coordination and efficiency among various agencies through a decentralized ledger that tracks resources and automates processes with smart contracts. Additionally, blockchain's secure data sharing and traceability capabilities strengthen the management of aid and protect sensitive information. Resource optimization ensures that aid and resources are allocated efficiently to maximize their impact and minimize waste. The process of analysing data and streamlining logistics improve the speed and effectiveness of response efforts. This approach enhances overall operational efficiency, reducing costs and improving the effectiveness of disaster relief operations.

Recovery and reconstruction focus on restoring communities to their pre-disaster state or better by rebuilding infrastructure and homes. This process involves assessing damage, prioritizing needs and implementing sustainable solutions to ensure long-term resilience and stability to support Priority 3. Effective recovery and reconstruction help communities regain normalcy, support economic recovery and strengthen their ability to withstand future disasters. Hybrid Framework of Technology Impact in HADR is developed to close the technology gaps in the existing HADR framework and accordance with the Sendai Framework as shown in Figure 6. The partial validation of the proposed HADR framework during Tropical Typhoon Trami in the Philippines (2024) has provided critical operational insights. The Royal Malaysian Air Force (RMAF) deployment demonstrated the importance of technologies such as secure communications and geospatial mapping to enhance situational awareness. However, the operation revealed persistent gaps, including the lack of seamless communication, limited interoperability among platforms and the absence of an integrated Common Operating Picture (COP) system. These limitations significantly constrained coordination and decision-making efficiency. This reinforces the imperative for ASEAN HADR frameworks to incorporate interoperable and technology-driven capabilities.

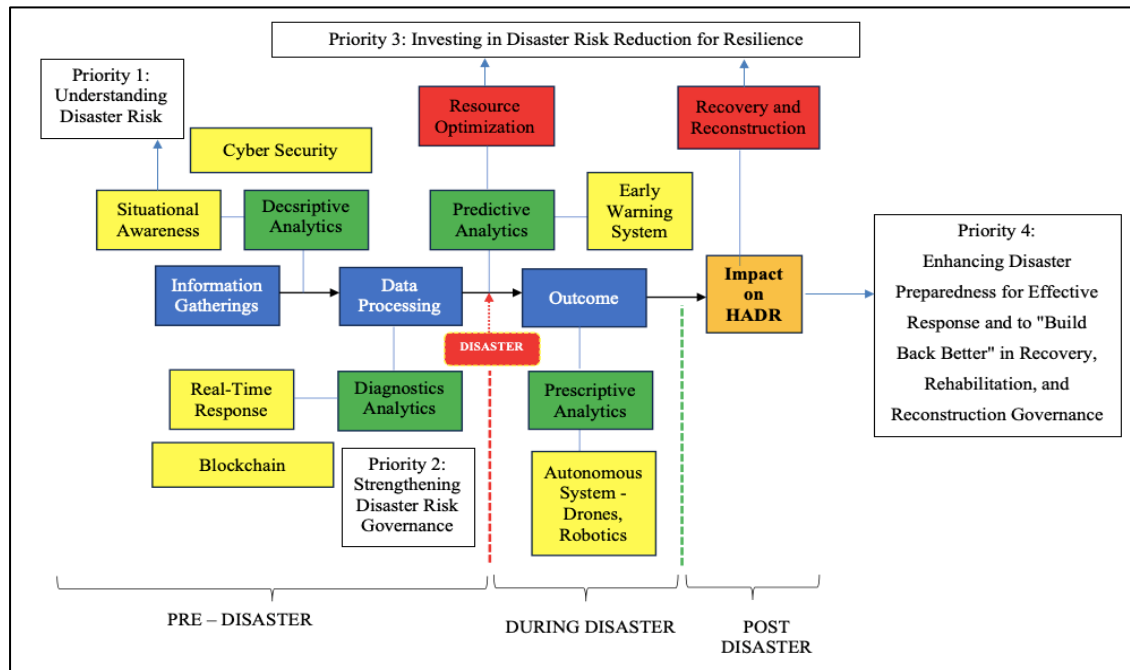


Figure 6: Hybrid Framework of Technology Impact in HADR (Krishnan, S. 2024)

Effect of Technology Attributes in HADR Resilience

The DIKW model (Data, Information, Knowledge, Wisdom) illustrates how raw data evolves into meaningful insights. In the HADR context, data are unprocessed and often disorganized, consisting of both quantitative and qualitative elements. When structured and given context, this data becomes information, making it more meaningful. Further analysis and synthesis of information, based on experience or understanding, transforms it into knowledge that provides deeper value for decision-making in disaster scenarios. It involves cognitive processing and understanding of the entire data ecosystem. Wisdom is the ability to make sound judgments and decisions based on knowledge (Peters et al., 2024). It involves applying knowledge in a practical, ethical and insightful manner. It has deep understanding and practical application. It provides intact answers to all questions and queries. This involves a tenacious and rigorous process of managing data history, insight and behaviour pattern considerations.

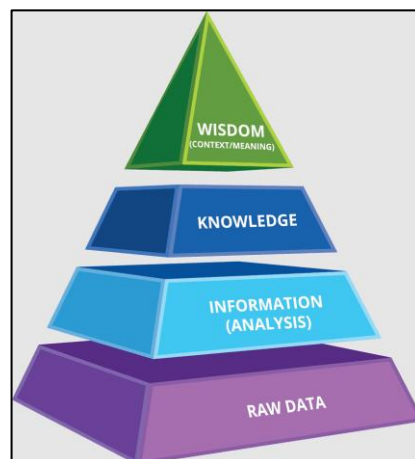


Figure 7: Traditional DIKW Model (Baškarada & Koronios, 2013)

The traditional DIKW model has been improvised into AI environment as shown in Figure 8. High volume of collected data from sensors from the physical space will form big data that holds the unstructured data related with HADR. Subsequently, information is gained by processed the big data that become valuable with the presence of correlation and behaviour pattern. Next, knowledge is obtained by adding value to the information with the analytics tools to assist decision making. Eventually, wisdom as the pinnacle of the model that able to prescribe the best solution, develop strategies and minimising the risks as well(Peters et al., 2024).

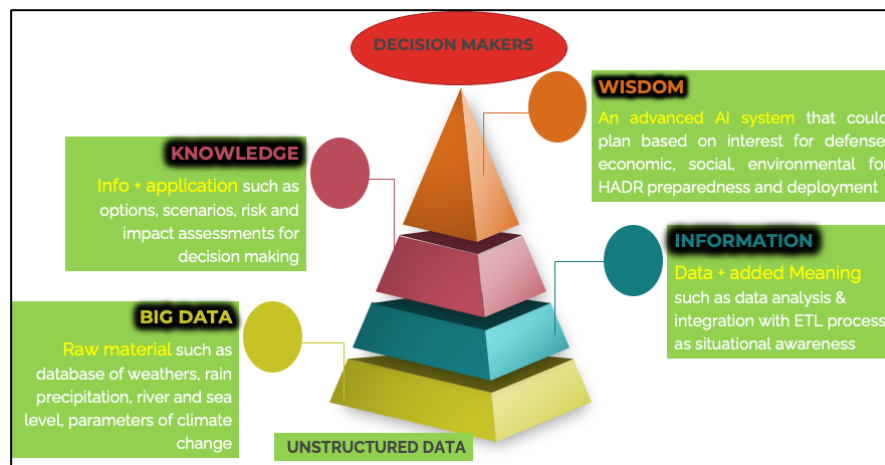


Figure 8: Migration of Traditional DIKW Model into AI Environment

The Sendai Framework are potential to be enhanced with advanced technology attributes to boost DRR and HADR operations. This includes integrating IoT sensors and machine learning algorithms for more accurate and timely early warning systems. It optimises satellite and mesh networks to ensure resilient communication during disasters, big data analytics and GIS for comprehensive risk assessment (Shakibaei et al., 2024). AI are best for decision support and decision making in HADR. Instance, drones and robotics can assist to carry out tenacious and risky SAR operations (Aretoulaki et al., 2023). Blockchain is suitable for secure supply chain and fund management where it can streamline and enhance response efforts (Khan et al., 2021). Additionally, mobile applications and VR simulations can improve public engagement and responder training (Kumsap et al., 2018). Besides it, smart infrastructure and renewable energy solutions can strengthen resilience (Khalifeh et al., 2022). Good state of cybersecurity ensures the integrity and reliability of critical communication and data systems during disaster scenarios. Technology attributes enhancement in Sendai Framework is discussed thoroughly in Table 7.

Table 7: Technology Attributes Enhancement in Sendai Framework

Technology Attributes	Key Enhancement	Purpose	Deductions
Early Warning Systems	IoT Sensors	Monitor environmental changes in real time	Enables timely alerts and improved situational awareness
	Machine Learning	Analyze historical and real-time data	Enhances predictive accuracy for natural hazards
	Multi-Hazard Integration	Issue alerts for multiple disaster types	Promotes comprehensive preparedness and early response
Communication Networks	Satellite Connectivity	Ensure communication during infrastructure failure	Maintains operational coordination
	Mesh Network Deployment	Establish resilient, decentralized networks	Secures reliable communications in affected zones
Data Analytics and	Big Data Platforms	Aggregate and process multi-source data	Informs strategic planning and risk assessment
	GIS Mapping Tools	Conduct spatial analysis and hazard mapping	Supports evacuation planning and resource allocation
Artificial Intelligence	Decision-Support Systems	Aid in emergency planning and real-time response	Optimizes resource use and impact forecasting
Robotics	Drones and Autonomous Systems	Assist in search and rescue operations	Access hazardous or remote locations safely
Blockchain	Supply Chain Tracking	Secure logistics of relief materials	Ensures transparency and accountability
	Fund Distribution Platforms	Manage and distribute aid effectively	Enhances trust and minimizes mismanagement
Community Engagement	Mobile Applications	Deliver alerts, training, and evacuation info	Improves public awareness and preparedness
	VR Training Simulations	Train responders using immersive scenarios	Enhances readiness and skill application
Participatory Mapping	Crowdsourcing Platforms	Involve communities in hazard identification	Leverages local knowledge for accurate risk mapping
	Open Data Sharing	Enable real-time disaster impact reporting	Improves situational awareness and stakeholder collaboration

Technology Attributes	Key Enhancement	Purpose	Deductions
Cybersecurity	Secure Communication Infrastructure	Protect communication systems	critical Prevents cyber disruptions during disaster response
	Cyber Incident Response Teams	Address threats during operations	Ensures system integrity and operational continuity

Recommendations of Technology Attributes in Sendai Framework

For the Sendai Framework in DRR, incorporating specific technology attributes can significantly enhance disaster management capabilities as shown in Table 8.

Table 8: Potential Technology Attributes in Sendai Framework

Attribute	Benefit	Action Plan
Interoperability	Facilitates effective communication and coordination among various agencies and stakeholders.	Design systems to integrate seamlessly with other technologies and platforms.
Real-time Data Collection and Analysis	Provides up-to-date information on disaster conditions, enabling timely decision-making and effective response strategies.	Implement sensors, IoT devices and data analytics platforms for real-time monitoring and rapid data processing.
Robust Communication Networks	Ensures continuous communication during disasters, even when conventional networks are disrupted.	Deploy resilient and redundant communication infrastructure, including satellite communications and mesh networks.
Geographic Information Systems (GIS)	Enhances situational awareness and aids in efficient resource allocation and planning.	Utilize advanced GIS tools for mapping, spatial analysis and visualization of disaster impact and resources.
Mobile and Cloud-based Platforms	Enables remote access to critical data and coordination tools, facilitating flexible and scalable disaster response operations.	Deploy mobile apps and cloud-based systems for information dissemination, coordination and resource management.
Artificial Intelligence and Machine Learning	Improves accuracy in disaster prediction, risk assessment and decision-making automation.	Integrate AI and ML for predictive modeling, risk assessment and automation of routine disaster response tasks.
Drones and Robotics	Provides rapid assessment of disaster zones, assists in reaching inaccessible areas and enhances human efforts in dangerous environments.	Utilize drones for aerial surveillance and robotics for search and rescue operations to augment disaster response efforts.
Blockchain Technology	Ensures accountability, prevents fraud and enhances efficiency in aid delivery processes.	Implement blockchain for secure and transparent tracking of aid

Community-based Platforms	Leverages local knowledge and enhances community resilience by aligning response efforts with actual needs of affected populations.	distribution and financial transactions. Develop platforms for community participation, crowd-sourced information sharing and tailored disaster response strategies.
Energy Resilience	Maintains functionality of essential services and communication networks during power outages caused by disasters.	Deploy renewable energy sources and backup power systems to ensure uninterrupted operations of critical infrastructure during disasters.

The proposed ASEAN countries for each attribute consider their geographical and technological capabilities, as well as their vulnerability to various types of disasters. These countries can benefit from targeted investments and collaborations in these areas to strengthen their disaster response capabilities.

Conclusion

Emerging technologies have the potential to transform humanitarian efforts from reactive responses to proactive strategies through earlier detection, faster response, and more effective actions. A hybrid technological framework can strengthen decision-making in HADR operations. Future integration of big data and artificial intelligence into Military Operations Other Than War (MOOTW) could further enhance situational awareness by aggregating diverse data sources such as satellite imagery, social media, and ground reports. AI-driven analysis can provide timely and actionable insights for military leaders to make informed decisions in complex environments. The novelty of this paper is the technology's impact of HADR in ASEAN. This hybrid framework of technology's impact on HADR has successfully provide an extension to Sendai framework of HADR (Krishnan et al., 2024). The proposed framework is based on establishing technology attributes in HADR. So, HADR in ASEAN should comply with the emerging technologies and IR 4.0. This is crucial to maintain the interoperability, provide real-time data to support situational awareness. At the back end, various analytics will be run rigorously and tenaciously to support the effectiveness of HADR.

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