Exploring the roles and challenges of disruptive technologies for emergency management in Aotearoa New Zealand

Lukas Kroher
Otto-Friedrich University Bamberg
lukas.kroher@gmail.com

Marion Lara Tan
Massey University
M.L.Tan@massey.ac.nz

Raj Prasanna
Massey University
R.Prasanna@massey.ac.nz

ABSTRACT

This work-in-progress paper presents preliminary findings from an exploratory workshop on disruptive technologies in emergency management in Aotearoa New Zealand. Thematic analysis identified three main themes on the role of disruptive technologies: (1) creating a common operating picture, (2) enhancing interaction, and (3) organising information. Despite the transformative potential of disruptive technologies, there are several challenges, including reliability and consistency of information, managing large volumes of data, integration and interoperability, and security and privacy concerns over data usage, among others. The study highlights the need for robust collaboration and resource-sharing mechanisms to leverage disruptive technologies in New Zealand's emergency management landscape. Future work will investigate these identified themes through additional interviews and workshops involving emergency management professionals. Further focus will examine the preliminary findings to the broader concept of situational awareness in emergency contexts.

Keywords

Disruptive technologies, emergency management, thematic analysis, exploratory study

INTRODUCTION

Aotearoa New Zealand (NZ) faces a range of natural hazards, including geophysical and hydrometeorological hazards. Earthquakes, a significant hazard, register approximately 20,000 events annually, with around 33 exceeding a magnitude of 5.0, posing risks to infrastructure (GeoNet, 2023). In the hydrometeorological context, flooding is the most frequently occurring hazard, projected to occur every eight months in NZ due to climate change implications (Mason et al., 2021). Cascading impacts could also trigger further hazards such as tsunami and landslides.

The consequences of hazards extend beyond the physical environment and can also have social impacts. As Goffman (1974, p. 379) aptly describes in his framework analysis, such negative experiences can result in a phenomenon he refers to as "reality anomically flutters". This phenomenon extends beyond individuals, manifesting on a macro level in the face of natural hazards, triggering a process of renegotiation and normalisation during highly destructive events. Such processes are pivotal, especially when emergency management teams and decision-makers synchronise their various perceptions with on-site realities. Therefore, efficient handling of information plays a key role in creating a picture of the situation that is as reliable as possible (Jayawardene et al., 2021). This process can be facilitated by technologies that sit in a moderating position between the individual and the situation (Hörl, 2011).

Previous studies have shown that technology can be important in the complex and dynamic emergency management system to support effective and timely decisions (Endsley, 1995; Prasanna et al., 2017). However, technology keeps evolving. Emerging and disruptive technologies such as artificial intelligence (AI), the Internet of Things (IoT), and Big Data are changing many fields, including disaster risk reduction and management (ITU, 2019). This evolution enables faster processing and sharing of critical information, adapting to the changing nature of disaster risks (Munawar et al., 2022). In this rapidly changing landscape, it is imperative that we update and advance research on exploring how technologies can be leveraged to enhance disaster risk reduction.

This study investigates disruptive technologies in emergency management in NZ. This work-in-progress paper presents preliminary findings from a workshop held in Auckland, NZ, on 7 November 2022, in alignment with the ISCRAM Asia Pacific Conference. The objectives of this study are twofold: (1) to investigate the role of technologies in the production process of generating the necessary information for responding to a disaster, and (2) to examine the challenges in using the information for the subsequent response process. Note that the data gathering for this study was conducted before major flooding events in January and February 2023.[1] Therefore, it is not within the scope of this study to include lessons learned from these events.

BACKGROUND

This section delves into key concepts underpinning the study and provides a brief overview of the current research landscape, crucial for understanding the interplay between disruptive technologies and emergency response.

Key Concepts

These terms are defined to provide context and assist consistency in addressing the topic of this study of disruptive technologies in emergency management.

- **Disasters** are multifaceted events causing damage, losses, and disruption to societies or communities (Peek et al., 2021). As defined by the United Nations Office of Disaster Risk Reduction, a disaster is a "A serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and capacity, leading to one or more of the following: human, material, economic and environmental losses and impacts." (UNDRR, 2017)
- **Disruptive technologies** are new technologies that can give rise to a new avenue of doing business or research (Munawar et al., 2022). In this study's context, these are technological developments that can provide potential solutions for improvements in emergency management (ITU, 2019).
- **Emergency management** encompasses the organisation and management of resources for addressing all aspects of emergencies, including preparedness, response, and recovery (UNISDR, 2009).

Current Research on the Topic

In recent years, emergency management has witnessed significant disruptions facilitated by technological advancements (Munawar et al., 2022). Academic publications in the past five years (2019 onwards) have frequently highlighted the pivotal role of various technologies in reshaping the landscape. Noteworthy technologies frequently mentioned in recent literature include Artificial Intelligence (AI), big data, sensors, Internet-of-Things (IoT), autonomous vehicles including unmanned aerial vehicles (UAV), blockchain, and fog/edge computing (see Table 1). It's important to note while Table 1 summarises the applications for these disruptive technologies and outlines the associated challenges, the list is not exhaustive. These examples provide a snapshot of prevalent technologies discussed in the field.

From the literature, these technologies can play a crucial role across the entire disaster lifecycle. However, the integration of disruptive technologies also has challenges. According to Munawar et al. (2022), one significant challenge is the absence of policies, especially on data governance. Much of the needed information (e.g. real-time data, infrastructure details) lies within city or municipal governance and policies, which may be hard to access. Data integration protocol is also needed to ensure the new technologies are aligned to provide information from proper data gathering and modelling (Akter & Wamba, 2019). For example, for a disaster management system to use big data, an enormous amount of location-specific data may come in during a disaster; the system should be capable of aiding agencies to usher this big data to become useful information to provide real-time actionable services to the people in need (Akter & Wamba, 2019).

[1] The January Auckland flooding and Cyclone Gabrielle were significant natural hazard events for NZ in 2023. insurance costs for these events are estimated at NZ$1.65 billion (ICNZ, n.d.) These events also resulted in loss of human life, with four people killed in the Auckland floods (RNZ, 2023a) and eleven people losing their lives during Cyclone Gabrielle (RNZ, 2023). Many individuals were left stranded and hundreds needed to be rescued from rooftops.

Table 1. Summary of frequently discussed disruptive technologies, applications, and challenges

Technology	Examples of applications	Challenges	References
Artificial intelligence	• Accelerate disaster management across all phases, e.g., geospatial data analysis for disasters. • Hazard assessment (e.g. cyclone intensity, floods, and landslides) • Impact assessment (e.g. infrastructure damage) • Crowd management and situation analysis, prediction, and evacuation planning • Sentiment analysis: find opinions or emotions on a specific topic	• Requires precise data with effective feature selection. • Large amounts of data and accuracy of data. • Fragmented efforts on narrow use cases without broader stakeholder collaboration; AI tools underutilized in decision-making. • Data sources may be inaccessible or incompatible with other datasets; data may not captured systematically.	(Arora et al., 2023; Munawar et al., 2022)
Big data (including social media) and cloud services	• Use of GIS and GPS for integrated hazard analysis with large datasets. • Use of social media and location data to find trends and threats for real-time monitoring (e.g. bushfires) • Helps identify critical events and needs assessment • Gauge public opinion to influence decision-making and offer early feedback on government policies.	• Protecting data confidentiality, privacy, and ownership • Storage and processing systems may struggle with performance delivery • Capability, including infrastructure & personnel • Availability, scalability, quality & interoperability.	(Akter & Wamba, 2019; Arora et al., 2023; Bania et al., 2023; Munawar et al., 2022)
Autonomous vehicles (e.g. UAV)	• Images captured by drones can be used for impact assessment to evaluate the situations.	• Battery, physical load, processing power, difficult manoeuvring conditions	(Munawar et al., 2022)
Blockchain	• Blockchain in disaster management aids collaboration through peer-to-peer communication and smart contracts. • Blockchain's sharing economy boosts resource management accountability and auditability. • System democratisation enables multi-disciplinary involvement whilst increasing the quality of decision-making.	• Lack of trust or understanding amongst stakeholders on blockchain technology.	(Cheklin et al., 2022; Krichen et al., 2024; Vermiglio et al., 2022)
Sensors, internet-of-things (IoT)	• IoT paired with AI enables early prediction using real-time data. • IoT tracks equipment in disaster management. • Sensors and IoT aid data collection, analytics, and early warnings. • Wireless autonomous networks assist communication without pre-existing infrastructure. • Supports both centralized and decentralized network architectures.	• The heterogeneous nature of interconnected devices poses several interoperability challenges.	(Arora et al., 2023; Bania et al., 2023; Munawar et al., 2022; Prasanna et al., 2022)
Fog/edge computing	• Ability to process data in real-time, closer to end-user devices, resulting in reduced response times without the intervention of the cloud; enables quick access to data and faster decision-making.	• Limited resources at the edge. • Data communication challenges.	(Bania et al., 2023; Militano et al., 2023; Prasanna et al., 2022)

With disruptive technologies, significant concerns such as security and privacy arise, as data availability also increases the risk of manipulation and unauthorised use (ITU, 2019). Another significant challenge lies in the high implementation and maintenance costs of these cutting-edge technologies (Akter & Wamba, 2019; Cheklin et al., 2022). There is a need for cost-effective solutions that deliver long-term benefits.

Much of the existing literature focuses on testing and providing sample use cases, but further research is needed to understand their implementation and performance during and post-disaster (Munawar et al., 2022). Understanding the role of collaboration is a research opportunity when utilising technologies. Closer collaboration facilitating effective sharing of resources is needed to utilise disruptive technologies for emergency management (Cheklin et al., 2022). Disruptive technologies cannot be fully utilised or scaled up when there is incomplete data sharing and ineffective use of resources (Cheklin et al., 2022).

Acknowledging the existing work, gaps, and opportunities in this area, this paper investigates more closely how emergency managers and technology researchers view the needs and challenges of utilising disruptive technologies for emergency management in NZ.

METHOD

Data Acquisition

A workshop was conducted to understand the technology needs and challenges for emergency management in NZ. The workshop was held on 7 November 2022 in alignment with the second ISCRAM Asia Pacific Regional Conference with the theme "Dealing with the Unexpected". The conference was held at RMIT University in Melbourne, Australia, with a satellite venue at AUT in Auckland, NZ. The workshop was held in Auckland to reach the target NZ-based participants.

The workshop was designed with two objectives in mind: (1) to investigate the role of technologies in the production process of generating the necessary information for responding to a disaster, and (2) to examine the challenges in using the information for the subsequent response process. With these, the workshop focused on exploring the technological desires and requirements of the emergency management sector. Particularly through a large-scale crisis scenario centred on situation awareness and decision-making needs. The workshop was held with subject matter experts (academics) and emergency management practitioners. The participants were formed into four focus groups to investigate the patterns of *doing-crisis* approaches. This method helps to connect unrelated individuals (and thus perspectives) from various backgrounds. Furthermore, the fluid nature of focus groups might trigger knowledge, experiences and emotions more effectively than face-to-face interviews (Witkowski et al., 2021). The workshop obtained peer-reviewed approval (Project number: 4000026842) under the ethical conduct code of Massey University for research with human participants deemed "low risk".

Participant Recruitment and Composition

Invitations for the workshop were dispatched to the Civil Defence Emergency Management (CDEM) groups, the National Emergency Management Agency (NEMA), scholars in disaster research and ISCRAM Conference attendees. This procedure ensured that academics (13 participants) and practitioners (18) were adequately represented in this focus group. Specifically, the latter group contains members from regional councils (8), representatives from different ministries (3), employees from NEMA (4), and participants from the lifelines sector (1) and the private technology sector (1). There were no admission prerequisites except for being physically present in Auckland. Conducting an in-person workshop in Auckland presents a limitation, as it could potentially introduce bias through the barrier of limiting attendance for those living further away.

Workshop Structure and Guide Questions

The workshop is centred around a hypothetical emergency scenario, which was presented to the participants: The Greater Wellington region is affected by long and strong ground shaking due to an earthquake (Magnitude 8.9, with shaking up to 10 MMI in Wellington) on the south-eastern coast of NZ's North Island. In addition to the damage caused by the tremors, the earthquake unleashed a series of tsunami waves that caused widespread flooding throughout the affected area.

The participants were then formed into groups, with each group consisting of academics and practitioners. Each group was tasked with the (imaginary) coordination of a national intelligence task force in their position as emergency management leaders during the post-disaster response phase in the first week. Against this, the focus group deliberated on tackling this situation for two hours, based on five guide questions aligning with the research objectives (see Table 2). The questions revolve around information and technology—questions 1 and 2 focus on efficiently handling information in response to the event. Questions 3, 4, and 5 revolve around using technology as part of the response strategies to the hypothetical earthquake.

Table 2. Guide questions to stimulate the discussion

Topic	Question	Aligning to objectives
Focus on information	1. What are the *information/intelligence needs* to build situation awareness for the initial first week to achieve your goals for response and recovery	(1) to investigate the role of technologies in the production process of generating the necessary information for responding to a disaster
	2. What *challenges* do you expect to arise when acquiring and using information during the first week of response and recovery?	(2) to examine the challenges in using the information for the subsequent response process
Focus on technology	3. What technological tools and solutions are *currently* available (in practice or research) to address the information needs and problems?	(1) and (2)
	4. What *new* technological tools and solutions can be developed to enhance situation awareness?	(2)
	5. What technologies should be *prioritised* to be researched, re-evaluated, and developed?	

Data Analysis

Qualitative research methodology is employed to analyse the workshop data. Following this epistemological understanding, the experiences of each speaker contribute to institutionalising a shared, intersubjective reality (concept originating from Berger et al., 1967). Braun and Clarke (2006) suggest a reflexive thematic analysis (TA) to convey the general trends of focus group discussions. As per their suggestion, single themes could be understood as "pattern(s) of shared meaning" (Braun et al., 2019, p. 845) that are arranged around a central concept. In consequence, the (1) themes are detached from single speaker positions, and the (2) themes emerge through (a) discourses within the focus groups and (b) through the active, moulding role of the researcher (Braun et al., 2019). Responses were not coded or differentiated according to the speaker's identity or affiliation due to the methodological preconditions of the thematic analysis and privacy concerns. The thematic analysis follows a six-step process, as detailed in Table 3.

Table 3. Thematic analysis (based on Braun et al., 2019)

Phase	Explanation/ justification	Application
Transcription	Make the data material accessible for systematic analyses	AI-supported conversion from audio to text
Familiarisation	Getting used to data	Rereading, making casual notes
Coding	A systematic process of making sense of the data	Deductive coding of the semantic meaning of each segment (through the guide questions)
Constructing themes	Merge codes with similar meanings to provisional themes	Unstructured, inductive organisation of codes around similar semantic meanings (independent of pre-given structure)
Revising themes	Define and establish themes within itself and in their relation to each other.	Rigorous merging of code groups; investigating similarities on latent meaning within each group, leading to a differentiation process to other themes.
Producing report	Final coherence check how well themes can be augmented	Presenting the final themes to a scientific audience

The thematic analysis started with transcribing the recording of each focus group discussion with the assistance of AI technology. Following a brief familiarisation period with the database, the coding process began by tackling the transcribed data sequentially through each guide question, and every segment was allocated a label denoting its semantic meaning. The deductive themes guided by the workshop questions are illustrated in Figure 1.[2] The

[2] This includes the initial segments from Q1 to Q4. As Q5 does not contain any new aspects (it only highlights

codes were then categorised based on comparable explicit sense, where analysing the data was not limited to the guide question structure in this process. No longer limited to pre-defined structures, the codes were aggregated and re-organised by collapsing and combining the codes with similar semantic meanings.

Further into the thematic analysis process, the research team identified three main themes (See Figure 2), which were then reviewed to ensure clear definitions and distinctions. This also necessitated the generalisation of meaning by transforming the themes into a more implicit and latent level. The methodological approach used in this study is thus aligned with the principles of grounded theory, which includes theoretical sampling, transcription, coding, and contrasting (Bryant & Charmaz, 2007)[3].

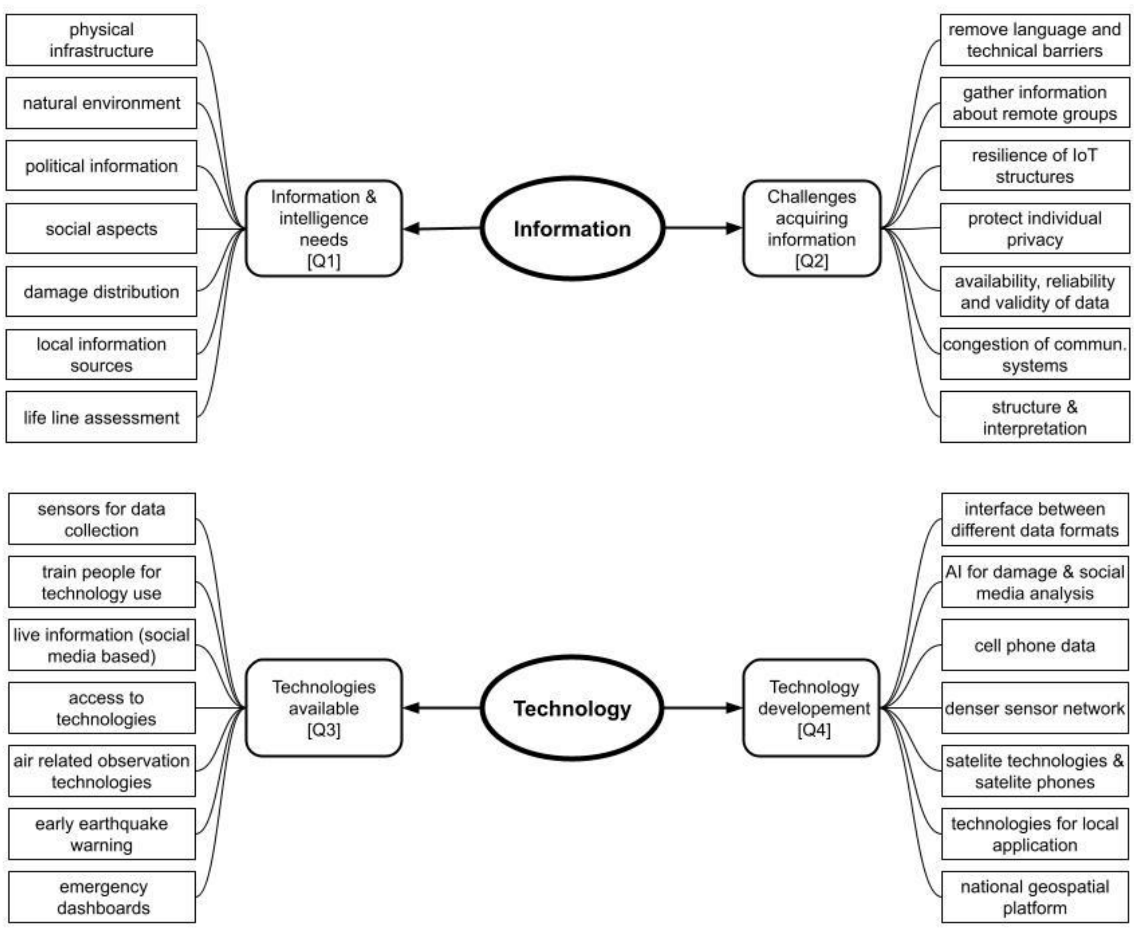

Figure 1. Initial themes deducted from guide questions

PRELIMINARY RESULTS

Through the production process of generating necessary information for response, the preliminary findings show that there are three main themes for disruptive technologies' role in emergency management: (1) the common operating picture (COP), (2) the interaction (IA), and finally, (3) the organisation of information (OI). Figure 2 illustrates the graphical composition of the resulting thematic analysis. Alongside these themes, we highlight some of the challenges encountered.

Common Operating Picture (COP)

The first theme is *associated with achieving a stable information status* for all involved in the emergency

aspects already mentioned as important), it is not included.

[3] Guest et al. (2012, p. 13) stress, that the Thematic analysis "method does not preclude theoretical development", which is also part of the grounded theory idea. However, he does not clarify whether this implies a totally autonomous macro theory or a middle-range proposition. The latter could be provided by the thematic analysis during the generalisation step.

management processes; this concept was commonly referred to by the participants as the 'Common Operating Picture'. The participants desire a reliable and statically rendered common picture to make sound decisions. Statically rendered means information that is consistent and with little ambiguity. The following participant's quote highlights the detailed questions that can arise from responders to help develop COP for decision-making:

> *Are the roads open or shut? My top priority is to know whether the state highways are open and then the local roads. Next, are the ports impacted? Can [they] roll on, roll off? [...] Can gear ships and other kinds of ships operate? What's the impact on the fuel system? From the wharves at the ports to the tank farms, which are normally low-lying at [parts]? [...] Impacts on service stations and [...] the impacts on the airports, [...] all of these tell us what the impacts on the supply chain are. Can food be delivered, and water and response activities be done?* (Group C participant)

When discussing the COP theme, the participants were particularly interested in learning about the status of lifelines, the physical environment, and the social aspects of the situation. Their interest in lifeline assessment looks into information about the availability of essential goods; this includes power, fresh water, food and medical support in hospitals. The physical aspects of COP relate to knowing more about the built environment, including evaluating critical infrastructure, such as accessibility to ports, roads, railways, and airports. The COP theme also involves learning about the disaster situation's social aspects, covering the damage distribution from a social needs perspective.

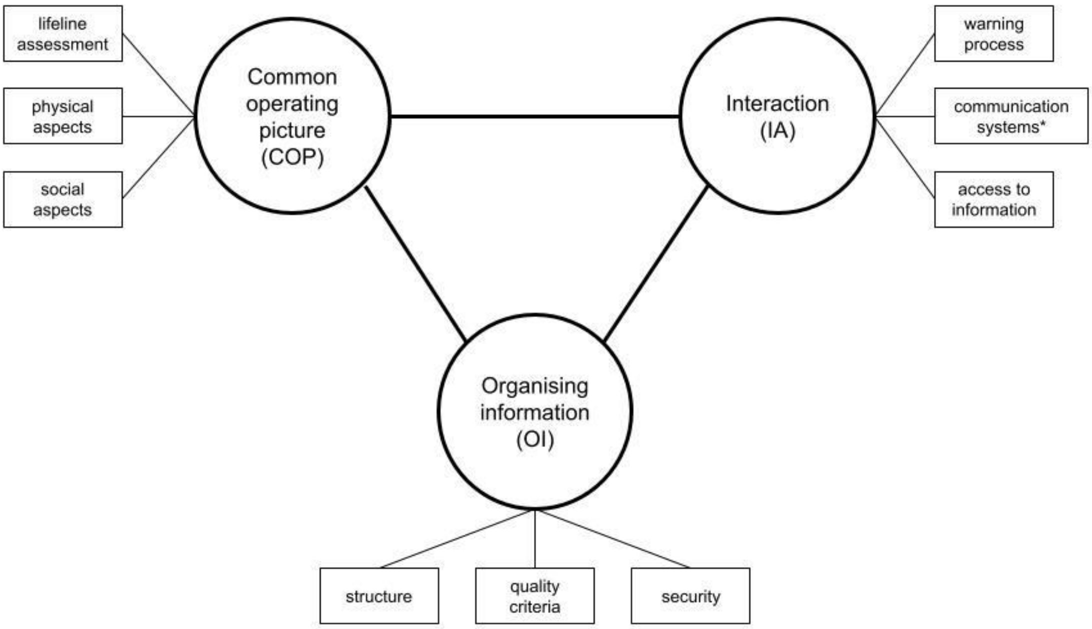

Figure 2. Visualisation of the preliminary results from the thematic analysis

To build a COP, participants acknowledge the importance of detailed information, which may be voluminous and come from multiple sources. Participants recognise the dynamic and emerging nature of disasters and thus multifaceted. Therefore, disruptive technologies' role is to gather reliable data and ensure the stability of the picture to withstand and integrate new players and emerging information. Hence, COP, although desired to be stable, must be adaptable, always to construct a more reliable awareness of the current situation. The technologies participants identified relating to COP include remote sensing and resilient sensor networks to aid impact assessments. The participants also mentioned the need to have the ability to process large amounts of information in quicker timeframes (i.e. AI and big data).

Interaction (IA)

The IA theme describes a *dynamic information exchange process* within and between the emergency managers and affected people. This flow of information can involve different technologies and revolves around multiple stakeholders, including providing information within and from the authorities and ultimately interacting with the information from those affected. Quotes from the participants highlight the interaction theme with emergency managers and the affected people:

> *I've just said one of the initial challenges is going to be actually around communications and actually being able to share data and share intelligence. Yeah, because it's going to be significant losses of infrastructure like fibre breakages, yeah* (Group C Participant).
>
> *I guess how accessible is it both from [...] a physical device but [also] is it in a way [in a] language you understand or a format you understand?* (Group B Participant)

When the discussion relates to the IA theme, it often revolved around interactions regarding the overall warning process, the role of communication systems, and the accessibility of information. An effective *warning process* is essential to give people the best chance to take protective actions. Participants highlighted that the process is not just technological but involves human and organisational processes. A working *communication system* is the core basis for all interaction during emergencies. Therefore, its maintenance is a crucial aspect of emergency response and thus holds great priority among workshop participants. Participants emphasised that excessive communication volume can pose a considerable challenge to the system, especially on the initial day following the disaster. This escalates the likelihood of system failure due to congestion during this critical phase. Participants highlighted that disruptive technologies can be the source of congestion (e.g., multiple data points, including social media) and a solution (e.g., IT systems incorporating AI, big data, and cloud services).

Participants highlighted multiple examples of disruptive technologies that aid in providing access to crucial information. This includes satellite imagery, use of UAVs, sensor networks, and social media. The ability to receive and communicate this message also relies upon access to suitable technical apparatus. On a societal level, access to information lies in reducing barriers to interpreting warnings and instructions, for example, eliminating language barriers and designing warnings with minimal complexity for ease of comprehension. The distribution and receipt of information also depends on various facts, among others, such as age (i.e., digital divide) and way of life (i.e., urban vs. rural). Access to crucial information serves as the basis for engaging with affected individuals.

Organisation of Information (OI)

The OI theme describes the *all-encompassing mechanism to store, analyse, and extract justifiable meaning* from incoming data. This includes data gathered automatically or through human input. Particular topics highlighted in the OI theme include: structure of incoming data, aspects and challenges around quality standards, and a secure handling of sensible information. Quote from participants highlights the OI theme:

> *I think definitely AI is coming. [...] so this can help us to quickly identify whether, for example, the building has been damaged or it is not [...] So you have texts, pictures or also other 3D geospatial data, so you need different type of technologies to process them. But I think, in general, AI I think can help us to reduce the human efforts.* (Group B Participant)

Different data types become available during emergencies and interpreting them will require effort. For example, for social media, data types include pictures, text, or geotagged information. Even geographical data can be presented in different formats (e.g. polygons vs. points vs. lines). Participants highlighted that in NZ, there is no national consensus on how to manage data, so every institution (e.g. different regional councils) maintains their own data collection. As a result, participants highlighted the role of disruptive technologies in standardising data types and making them interoperable. It was mentioned that AI holds a significant role in structuring incoming data. Therefore, AI-based methods such as targeted filtering for specific keywords and hashtags (for social media analysis), natural language processing, and sentiment analysis can be used. [4]

The quality of the information is another significant topic for OI. Quality includes the data's reliability (trustworthiness) and validity (no bias). Evaluating data quality can strain human resources during a crisis; this is where AI can help cross-check various data formats and sources to enhance the quality of interpretations. The evaluation will also ascertain which councils or platforms offer the most accurate information on the physical environment and infrastructure as part of the quality review process.

[4] Note that the workshop was held before the public release of ChatGPT on 30 November 2022 (Lock, 2022).

Finally, since the data can come from multiple sources and may contain data about human beings, attention is also needed to the security aspects. Participants also highlighted the importance of honouring data privacy concerns.

DISCUSSION

In answering the paper's first objective of investigating the role of technologies in generating information for response, the results have shown multiple insights into disruptive technologies' role in emergency management through the three themes: COP, OI, and IA. These themes, in practice, are not isolated but influence each other, shaping decision-making processes during emergencies: forming a reliable COP relies on the structured interpretation of data within the OI, which informs the coordination of interactions (IA) during emergencies. COP is a critical bridge between OI and IA, facilitating informed and strategic decision-making in crisis scenarios.

To fulfil the second objective of the paper on examining the challenges in using the information for the subsequent response process, we have found several challenges relating to COP, OI, and IA. There are challenges related to the reliability and stability of the COP due to the dynamic nature of disasters and the need for consistent yet adaptable information. Managing large volumes of diverse data from multiple sources and integrating emerging information poses significant difficulties. Interaction (IA) challenges include maintaining effective communication and data sharing among stakeholders, managing technology congestion, and ensuring information accessibility and interpretation for diverse populations. Organisation of Information (OI) challenges encompass managing data structure and quality, validating data authenticity, and addressing security and privacy concerns. Aside from the themes, general challenges involve achieving interoperability across different platforms, mitigating human resource strain through AI-assisted data evaluation, and navigating ethical and security concerns associated with data usage and integration.

Aligning with the challenges highlighted in the workshop, recent events such as the Auckland Floods and Cyclone Gabrielle that occurred in NZ (after the workshop was conducted) have highlighted the vulnerability of existing, more traditional technologies to provide sustained sensing and communication networks during and post-disaster scenarios (Bush International Consulting, 2024). These incidents have exposed the limitations of current systems, particularly in maintaining continuous data transmission and providing good situational awareness for decision-makers. The disruption to sensing networks and communication channels during such events poses significant challenges for frontline responders and wider emergency management authorities in making timely and informed decisions (Delgado-Ferro et al., 2022).

Compared to more traditional technology-based systems, disruptive technologies have significant potential to aid disaster management, as highlighted in the literature (e.g. Munawar et al., 2022) and workshop discussions. While existing technology-based systems support various functional roles of emergency management and the associated tasks, they still face several limitations that may hinder their efficiency and effectiveness. Operationalising traditional technology-driven systems is often constrained by high costs, limited scalability, centralised architectures, and vulnerable technology infrastructure, hindering timely and effective disaster response and recovery efforts (Prasanna et al., 2022). Therefore, ensuring the reliability of our technological systems and infrastructure is paramount and foundational. Regarding post-event infrastructure management, connectivity, serviceability, and restoration are key elements to consider (Kongar et al., 2017).

Robust communication systems and infrastructure are fundamental components of effective emergency management. This includes the need for an adaptive but reliable COP, a working system for IA that incorporates the whole warning process to ensure communities have access to information, and for OI to have a structure that ensures data quality and security. However, despite its capabilities, the successful integration of disruptive technologies hinges on robust policy frameworks that facilitate stakeholder collaboration and resource sharing. However, realising the full potential of disruptive technologies in NZ necessitates addressing challenges related to incomplete data sharing and ineffective resource utilisation.

Limitations

Study limitations warrant consideration. Method limitations, such as the potential biases due to the in-person format and the workshop location in Auckland, may have influenced the workshop outcomes. Future research should address these limitations by expanding the scope of data collection, including holding multiple more data gathering options, including workshops and interviews with online options to attend, to ensure comprehensive coverage of relevant stakeholders and perspectives.

Temporal constraints imposed by the workshop's timing may limit the comprehensiveness and applicability of the workshop findings due to technological developments and disaster events. Notably, the workshop was held before the public release of ChatGPT, a significant development in generative AI, which could potentially alter perspectives on AI's utility in emergency scenarios. Furthermore, data gathering for this study was conducted before major flooding events in NZ during January and February 2023. Subsequent data collection efforts with subject matter experts and emergency manager practitioners could provide valuable insights into the changes and adaptations following these events.

Future Work

While this study provides preliminary insights into the COP, OI, and IA themes and the associated challenges, future investigation by the research team will delve deeper into the sub-themes in this study and explore the intricate interconnections between COP, OI, and IA in greater detail. Comparative analysis between COP and the broader concept of situational awareness could provide valuable insights into their overlapping and distinct aspects, further enriching our understanding of information management in emergency contexts. Future work by the research team includes conducting follow-up interviews or workshops with more emergency managers in NZ.

Moreover, future studies should focus on use cases in simulated or testing environments. Implementation and evaluation studies would provide insightful, actionable recommendations for enhancing NZ's emergency management practice and policy development. Furthermore, social science studies could explore opportunities to study collaboration and partnerships between researchers, practitioners, and policymakers. By translating the insights gained from this research into practical interventions and policy recommendations, stakeholders can effectively address challenges related to data sharing, resource utilisation, and technology integration in emergency management.

REFERENCES

Akter, S., & Wamba, S. F. (2019). Big data and disaster management: a systematic review and agenda for future research. *Annals of Operations Research*, *283*(1–2), 939–959. https://doi.org/10.1007/s10479-017-2584-2

Arora, S., Kumar, S., & Kumar, S. (2023). Artificial Intelligence in Disaster Management: A Survey. In *Lecture Notes in Networks and Systems* (Vol. 552). Springer Nature Singapore. https://doi.org/10.1007/978-981-19-6634-7_56

Bania, A., Iatrellis, O., & Samaras, N. (2023). Information Communication Technologies (ICTs) and Disaster Risk Management (DRM): Systematic Literature Review. In *Lecture Notes in Intelligent Transportation and Infrastructure*. Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-23721-8

Berger, P. L., Luckmann, T., & Light, D. W. (1967). The social construction of reality : a treatise in the sociology of knowledge. *American Sociological Review*, *32*(137). https://doi.org/10.2307/3710424

Braun, V., Clarke, V., Hayfield, N., & Terry, G. (2019). Thematic Analysis. *Handbook of Research Methods in Health Social Sciences*, 843–860. https://doi.org/10.1007/978-981-10-5251-4_103

Bryant, A., & Charmaz, K. (2007). *The SAGE Handbook of Grounded Theory*. SAGE Publications Ltd. https://doi.org/https://doi.org/10.4135/9781848607941

Bush International Consulting. (2024). *Hawke's Bay Civil Defence and Emergency Management Group Respones to Cyclone Gabrielle*. https://www.hbemergency.govt.nz/assets/Uploads/HBCDEM-Response-to-Cyclone-Gabrielle-Final-Report.pdf

Cheklin, M., Naeni, L. M., & Killen, C. (2022). Opportunities for Application of Disruptive Technology in a Disaster Management System to Address Gaps in Australian Bushfire Response. *45th AUBEA Conference*, 282–292.

Delgado-Ferro, F., Navarro-Ortiz, J., Chinchilla-Romero, N., & Ramos-Munoz, J. J. (2022). A LoRaWAN Architecture for Communications in Areas without Coverage: Design and Pilot Trials. *Electronics (Switzerland)*, *11*(5). https://doi.org/10.3390/electronics11050804

Endsley, M. R. (1995). Toward a theory of situation awareness in dynamic systems. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *37*(1), 32–64. https://doi.org/10.1518/001872095779049543

GeoNet. (2023). *Earthquake Statistics*. https://www.geonet.org.nz/earthquake/statistics_long

Goffman, E. (1974). Frame analysis: An essay on the organization of experience. In *Frame analysis: An essay on the organization of experience.* Harvard University Press.

Guest, G., MacQueen, K., & Namey, E. (2012). *Applied Thematic Analysis*. https://doi.org/10.4135/9781483384436

Hörl, E. (2011). *Die technologische Bedingung: Beiträge zur Beschreibung der technischen Welt*. Suhrkamp Verlag.

ICNZ. (n.d.). *Cost of natural disasters*. Insurance Council of New Zealand. https://www.icnz.org.nz/industry/cost-of-natural-disasters/

ITU. (2019). Disruptive technologies and their use in disaster risk reduction and management. In *International Telecommunication Union*.

Jayawardene, V., Huggins, T. J., Prasanna, R., & Fakhruddin, B. (2021). The role of data and information quality during disaster response decision-making. *Progress in Disaster Science*, 100202. https://doi.org/10.1016/j.pdisas.2021.100202

Kongar, I., Esposito, S., & Giovinazzi, S. (2017). Post-earthquake assessment and management for infrastructure systems: learning from the Canterbury (New Zealand) and L'Aquila (Italy) earthquakes. *Bulletin of Earthquake Engineering*, *15*(2), 589–620. https://doi.org/10.1007/s10518-015-9761-y

Krichen, M., Abdalzaher, M. S., Elwekeil, M., & Fouda, M. M. (2024). Managing natural disasters: An analysis of technological advancements, opportunities, and challenges. *Internet of Things and Cyber-Physical Systems*, *4*(September 2023), 99–109. https://doi.org/10.1016/j.iotcps.2023.09.002

Lock, S. (2022). *What is AI chatbot phenomenon ChatGPT and could it replace humans*. The Guardian. https://www.theguardian.com/technology/2022/dec/05/what-is-ai-chatbot-phenomenon-chatgpt-and-could-it-replace-humans

Mason, K., Lindberg, K., Haenfling, C., Schori, A., Marsters, H., Read, D., & Borman, B. (2021). Social vulnerability indicators for flooding in Aotearoa New Zealand. *International Journal of Environmental Research and Public Health*, *18*(8). https://doi.org/10.3390/ijerph18083952

Militano, L., Arteaga, A., Toffetti, G., & Mitton, N. (2023). The Cloud-to-Edge-to-IoT Continuum as an Enabler for Search and Rescue Operations. *Future Internet*, *15*(2). https://doi.org/10.3390/fi15020055

Munawar, H. S., Mojtahedi, M., Hammad, A. W. A., Kouzani, A., & Mahmud, M. A. P. (2022). Disruptive technologies as a solution for disaster risk management: A review. *Science of the Total Environment*, *806*. https://doi.org/10.1016/j.scitotenv.2021.151351

Peek, L., Wachtendorf, T., & Meyer, M. A. (2021). Sociology of Disasters. *Handbooks of Sociology and Social Research*, 219–241. https://doi.org/10.1007/978-3-030-77712-8_11

Prasanna, R., Chandrakumar, C., Nandana, R., Holden, C., Punchihewa, A., Becker, J. S., Jeong, S., Liyanage, N., Ravishan, D., Sampath, R., & Tan, M. L. (2022). “Saving precious seconds”— A novel approach to implementing a low-cost earthquake early warning system with node-level detection and alert generation. *Informatics*, *9*(25), 1–32. https://doi.org/https://doi.org/10.3390/informatics9010025

Prasanna, R., Yang, L., King, M., & Huggins, T. J. (2017). Information systems architecture for fire emergency response. *Journal of Enterprise Information Management*, *30*(4), 605–624. https://doi.org/10.1108/JEIM-12-2015-0120

RNZ. (2023). *Cyclone Gabrielle updates: Death toll rises, half of uncontactable reports resolved*. RNZ. https://www.rnz.co.nz/news/national/484453/cyclone-gabrielle-updates-death-toll-rises-half-of-uncontactable-reports-resolved

UNDRR. (2017). *The Disaster Risk Reduction (DRR) Glossary*. UNDRR. https://www.undrr.org/terminology/disaster

UNISDR. (2009). *2009 UNISDR Terminology on Disaster Risk Reduction*. International Strategy for Disaster Reduction. https://www.undrr.org/publication/2009-unisdr-terminology-disaster-risk-reduction

Vermiglio, C., Noto, G., Rodríguez Bolívar, M. P., & Zarone, V. (2022). Disaster management and emerging technologies: a performance-based perspective. *Meditari Accountancy Research*, *30*(4), 1093–1117. https://doi.org/10.1108/MEDAR-02-2021-1206

Witkowski, K., Remington, C. L., & Ganapati, N. E. (2021). Focus group research in disaster and emergency management. In J. Rivera (Ed.), *Disaster and Emergency Management Methods:* (Issue 1, pp. 123–141). Routledge. https://doi.org/10.4324/9780367823948-10