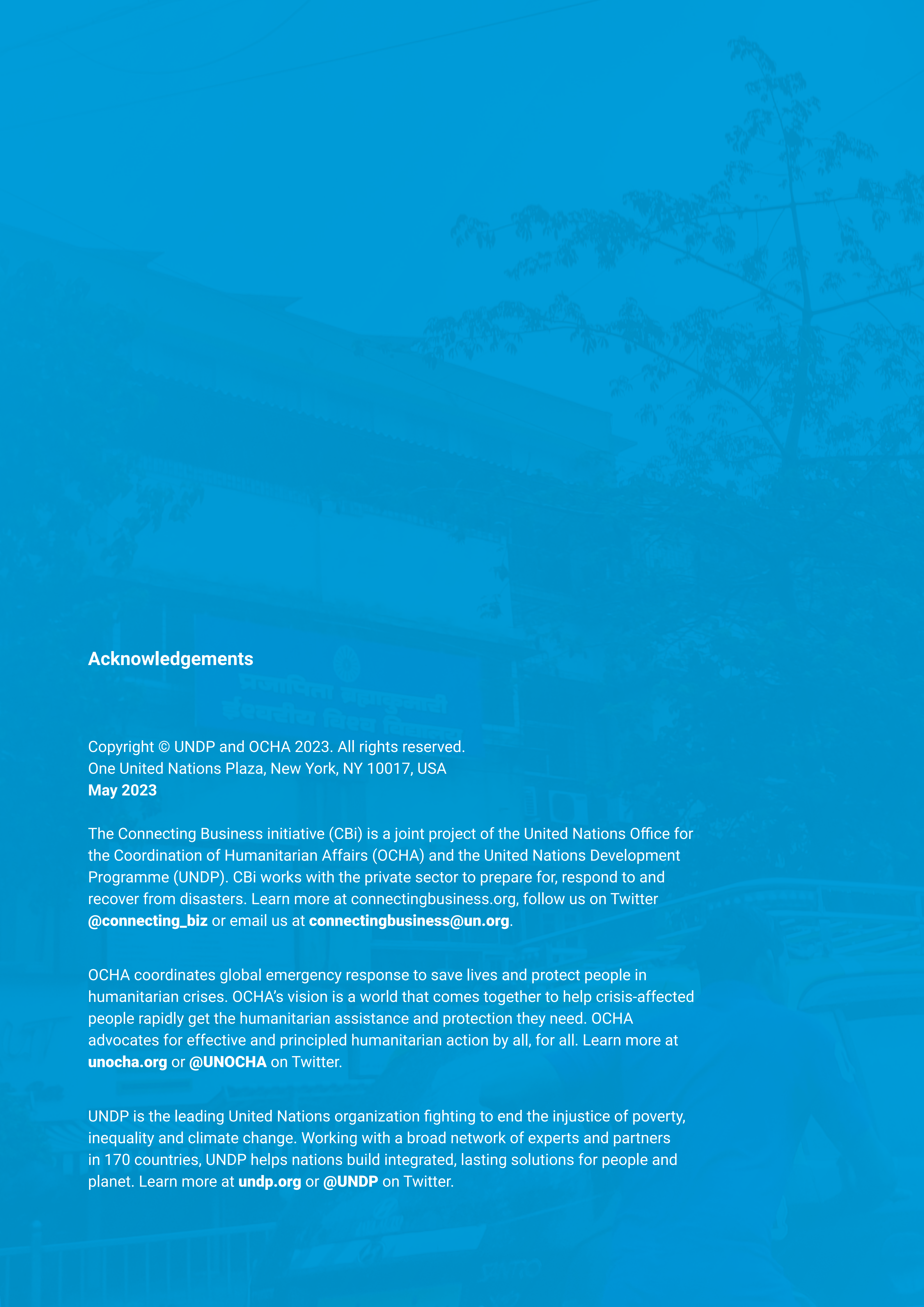
INNOVATION IN DISASTER MANAGEMENT

Leveraging Technology to Save More Lives



Acknowledgements

One United Nations Plaza, New York, NY 10017, USA
May 2023

The Connecting Business initiative (CBi) is a joint project of the United Nations Office for the Coordination of Humanitarian Affairs (OCHA) and the United Nations Development Programme (UNDP). CBi works with the private sector to prepare for, respond to and recover from disasters. Learn more at connectingbusiness.org, follow us on Twitter **@connecting_biz** or email us at **connectingbusiness@un.org**.

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Authors

Gokhan Dikmener

Jonas Nothnagel

Dina Akylbekova

Martin Szigeti

Yoonseong Jung

Tiina Turunen

Huihua (Nara) Hu

Shahnaz Radjy

Peer reviewers

Jos Berens
Team Lead, Data Responsibility
Centre for Humanitarian Data

McDonald Nyoni
Head of Exploration
UNDP Malawi Accelerator Lab

Enzo Maria Le Fevre Cervini
Head of Sector
Collaborative Solutions, European Comission

Ardita Zekiri
Head of Solutions Mapping
UNDP North Macedonia Accelerator Lab

The report team would like to thank the partner organizations and the peer reviewers for their engagement and feedback.

The manuscript was edited by Victoria Patience and designed by Onurcan Acar.

The research team would also like to express its gratitude to ICPSD SDG AI Lab interns Michaela Furlong, Giomar Hexspoor, Jemima Dale, Sila Ordu and Shuyu Wang for their kind assistance during the research process.

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EXECUTIVE SUMMARY

Technological advances can help reduce the global death toll following extreme weather events, despite the increase in frequency and magnitude of such events and population growth. For this reason, the Connecting Business initiative (CBi), a programme supported by the United Nations Office for the Coordination of Humanitarian Affairs (OCHA) and the United Nations Development Programme (UNDP), partnered with the UNDP Istanbul International Center for Private Sector in Development (ICPSD) SDG AI Lab to better understand the role of technology in disaster management and the role of the private sector in spearheading the broader adoption of innovations that can save lives and livelihoods.

This report aims to introduce and raise awareness about key technologies for disaster management, illustrate how they are most commonly used and outline the main challenges and key considerations associated with them. The hope is that this will fuel advocacy around the use of technology to foster resilience. Extensive study, expert advice and real-world implementation have shown these technologies to be essential facilitators of catastrophe resilience that reduce casualties, preserve livelihoods and improve catastrophe preparedness, response and recovery.

The technologies in question include the following:

- 3D Printing
- artificial intelligence (AI)
- augmented reality and virtual reality (AR/VR)
- blockchain
- cloud technology
- communications networks and 5G
- crowdsourcing
- cyberphysical systems
- drones
- geographical information systems (GIS)
- Internet of Things (IoT)
- remote sensing
- social media

Contemporary disaster management is inherently reliant on technology. This report explores private sector engagement in depth, aiming to clarify how better to integrate the private sector into technology-fuelled disaster management. By examining the factors affecting the inclusion of technology and exploring the potential benefits, the report sheds light on how technology — and technology spearheaded by the private sector in particular — can effectively enhance disaster management practices.

The report begins by introducing key technologies and use cases as well as challenges and opportunities related to their implementation. The next section homes in on the potential impact of technology in disaster management, especially for prediction and early warning systems. Case studies showcase innovations from a range of companies big and small to better illustrate their relevance.

However, as technology is mainstreamed in disaster management, digital divides remain. The greatest challenges to bridging these divides include limited or difficult access to high-quality data and a lack of technical expertise among practitioners. Gender and digital literacy are also important factors to address.

From observations in the field, the following recommendations for advancing technology-driven private sector disaster preparedness, response, recovery and resilience were made:

A standardized assessment framework for the digital maturity of the private sector in each context should be developed to ensure that the digital maturity and readiness of the private sector are assessed as precisely as possible.

The resources needed for technology-enhanced disaster response must be made available and accessible, possibly through funding opportunities and partnerships between the public, private and academic sectors.

Humanitarian organizations need to be incentivized and motivated to incorporate new technologies into their working practices, for example by providing training sessions on the importance of these technologies and addressing financial risk by encouraging partnerships.

The report contains examples from CBi Member Networks in Mexico, the Philippines and Vanuatu that showcase the power of business when its resources are used to improve disaster preparedness, response and recovery through a collaborative framework.

The report and its findings inspired the development of the Frontier Technology Radar for Disaster Risk Reduction (FTR4DRR). The radar systematically tracks frontier technologies as they are developed and categorizes these solutions by technology type, disaster/crisis type and maturity.

While there is still much to be done in the field of technology for disaster management, we hope this report will inspire and guide humanitarian and development practitioners to better understand the potential of partnering with the private sector—not only as a source of funding but also as a source of innovation and impact.

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INTRODUCTION

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Between 1960 and 2019, the number of natural disasters has increased from an average of 39 to 396 per year (Institute for Economics and Peace, 2020). In the same period, the global population has more than doubled, going from 3 billion to 8 billion (Coi, 2022). Despite these trends, deaths from natural disasters have decreased annually over the past century, falling from over one million in the mid-1900s to an average of 60,000 in the past decade (Ritchie, Rosado and Roser, 2021). Two factors likely contributed to this positive development: general advances in disaster preparedness and response and the increased use of technology in disaster management. Early warning systems and artificial intelligence (AI) have protected many people from disasters. Drones and remote sensing reduce the time it takes to find and rescue victims. Cloud storage and crowdsourcing help humanitarian responders receive information faster. This increase in frontier technologies has shown the potential to improve prevention measures, increase response efficiency and speed up recovery. While natural hazards affect many people's lives, it is often man-made factors that determine how severe their consequences are. Although technologies have reduced many risks associated with natural hazards, they come with their own risks and challenges that must be considered before their use is mainstreamed in disaster management activities.

The private sector has access to resources that can help humanitarian agencies implement the aforementioned technologies while also benefiting the private companies involved. By engaging in this space, businesses can better prepare their own approaches to disaster management and support the communities in which they operate. Furthermore, the private sector has an ethical responsibility to strengthen local resilience and ownership of technological disaster management capacities. This report is intended to serve as a practical guide to how the private sector can support disaster management through technology by identifying which frontier technologies are commonly used in disaster management and outlining their most common use cases.

The report uses the Connecting Business initiative (CBi) as a model to discuss the use of technology in disaster management in different country contexts and for different types of disasters. CBi is an initiative whose mandate is to engage the private sector before, during, and after crises. Operational and technical support are provided by the United Nations Office for the Coordination of Humanitarian Affairs (OCHA) and the United Nations Development Programme (UNDP). CBi operates in 16 countries and regions, with the aim of including the private sector in disaster responses with government support. CBi Member Networks encompass the Caribbean, Côte d'Ivoire, Ecuador, Fiji, Haiti, Indonesia, Kenya, Madagascar, Mexico, the Pacific Island States, Peru, the Philippines, Sri Lanka, Türkiye, Vanuatu and Viet Nam. Since these networks are mostly in developing countries with particularly vulnerable populations, we will take this into account and illustrate the risk and challenges technologies may pose for these populations.

The report and its findings inspired the development of the Frontier Technology Radar for Disaster Risk Reduction (FTR4DRR), which was officially launched in 2022. The FTR4DRR systematically tracks frontier technologies as they are developed so that technological solutions can be categorized by technology type, disaster/crisis type and maturity level. It is expected to encourage knowledge- and experience-sharing among development stakeholders on the use of frontier technologies in disaster and conflict contexts. The FTR4DRR highlights how technological solutions could benefit those working in risk reduction, response and recovery in disaster contexts. It helps development stakeholders to navigate the variety of existing and emerging technologies and their possible use cases.

CHAPTER 1

LANDSCAPE ANALYSIS

01

CHAPTER 1

LANDSCAPE ANALYSIS

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This section examines current technology that is likely to change through implementation and development efforts. We attempt to assess the potential for technologies and how they fit into the disaster management cycles of preparedness, response, recovery and resilience.

1.1 TECHNOLOGIES IN FOCUS

This report primarily addresses frontier technology (UNESCAP, 2018) and examines the gap between technological knowledge and the implementation of this. The technologies were chosen based on strategic criteria: they need to have already been successfully implemented in disaster management, mutually support one another, be among the most common available options, and represent the diverse range of resources now available. The ensuing section delves into a comprehensive exploration of the following technologies and intended use cases:

- **3D printing:** enables tailored solutions for critical needs in disaster-affected areas.
- **Artificial intelligence (AI):** improves disaster response and humanitarian aid by extracting and analysing critical data, predicting the severity of health crises and natural disaster risks, reuniting refugees with their families, identifying at-risk

areas, supporting asylum case management and supporting peacebuilding and negotiations.

- **Augmented reality and virtual reality (AR/VR):** improves disaster management and can be used for education, disaster relief planning, donation drives, information-sharing, virtual social spaces for remote meetings, and to aid search and rescue efforts with real-time data and simulations, ultimately enhancing disaster preparedness and response.

- **Blockchain:** increases transparency and efficiency in response and recovery, and can be used for supply chain management, donor finance, cash programmes, crowdsourcing and refugee digital IDs.

- **Cloud technology:** facilitates business continuity, enhances the management, processing and sharing of data, and creates efficient remote work environments.

- **Communications networks and 5G:** used to create localized networks for humanitarian teams, data processing and innovative solutions like THOR mobile and Starlink that guarantee communication even in challenging conditions.

- **Crowdsourcing:** enables geotechnology applications, crisis information gathering, digital volunteering, communication and situational awareness, making it a valuable resource for fundraising, volunteer coordination, information-sharing and disaster recovery efforts.

- **Cyberphysical systems:** improve the efficiency of 3D printing and IoT applications and enhance disaster preparedness, mitigation and response activities.

- **Drones:** provide timely, cost-effective information for disaster planning, response and recovery by creating comprehensive maps, assessing damage, assisting in search and rescue missions and delivering emergency supplies.

- **Geographical information systems (GIS):** used to help map, monitor, evaluate and predict disease outbreaks, identify disaster-prone locations, simulate disaster spread, make evacuation plans and assist reaction and recovery.

- **Internet of Things (IoT):** provides early warning systems, tracks personnel and resources during response, and monitors disaster recovery. IoT integration improves disaster management by providing data sets, situational awareness and data exchange across enterprises.

- **Remote sensing:** used to track storms, predict weather, forecast floods, assess vulnerability, map the location and monitor the severity of disasters and aid in damage assessment during the recovery stage. Satellite images and infrared sensors provide safe and effective remote data collection for urban and rural locations.

- **Social media:** X (previously Twitter) and Facebook provide disaster alerts, emergency communication and safety updates. Social media promotes partnerships, linkages and networks, promoting crowdsourcing and the transmission of disaster-specific information.

1.1.1 3D PRINTING

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What is 3D printing?

3D printing, also known as additive manufacturing, is a way of producing three-dimensional objects from a digital model by depositing or joining layers of a given material. There are various methods of 3D printing. Fused deposition modelling is when a long plastic wire is melted down and deposited in layers until the desired shape forms. Another method, stereolithography, uses a special resin that hardens when parts of it are exposed to an ultraviolet laser. A final method, synthetic laser sintering, works by fusing powdered materials using a high-powered laser.

3D printing in disaster management: Use cases

3D printing shows great potential in disaster management because it is a bespoke service that reduces the production time for parts while requiring few resources, and has already been used in disaster management settings. During the Covid-19 pandemic, personal protective equipment (PPE) was 3D-printed to respond to medical supply shortages. Likewise, the company 14Trees has found ways to build housing in 18 hours for less than US$10,000 and has 3D-printed housing and a school building in Malawi. Habitat for Humanity was the first operation to 3D-print a house for a homeless family in the United States, which it did in only 28 hours, at a cost 15–20 per cent below that of normal housing. Insight Surgery (previously known as 3D Life Prints) provides prosthetics for humanitarian response, and 3D printing has also been used to create replica bombs to train bomb disposal units.

It is often recommended that resource databases be created for humanitarian settings. One such example comes from Field Ready, a non-profit offering a catalogue of models for power generator parts, baby incubator parts and parts for clean water systems.

3D printing in disaster management: Challenges and opportunities

Despite the emergence of 3D printing as a low-cost solution in disaster management, its use is still limited by the need for materials, hardware and technological knowledge. While these inputs can often be procured in large cities, they are harder to access in less developed locations. Factors such as time sensitivity and extensive infrastructure damage heighten this challenge. The complexities of 3D printing can be addressed through access to free libraries of pre-made models of products. An individual thus only requires nuanced expertise when doing the modelling themselves. As Field Ready has demonstrated, 3D printing can be used to increase local capacity and build skills in local communities. In the future, integrating 3D printing projects throughout the UN could help mainstream its use.

The level of maturity of 3D printing used in disaster management has progressed significantly. All the same, the most commonly used 3D printing technology for producing Covid-19-related products was fused filament fabrication, which suggests that 3D printing is most often used to make relatively simple products like PPE and face shields.

Different forms of 3D printing technology need to be developed, and the importance of investment in the development of 3D printed products and a production and regulatory framework also needs to be acknowledged. To become a viable and credible alternative in emergency response scenarios, 3D printing for disaster management will likely require ongoing development and standardization.

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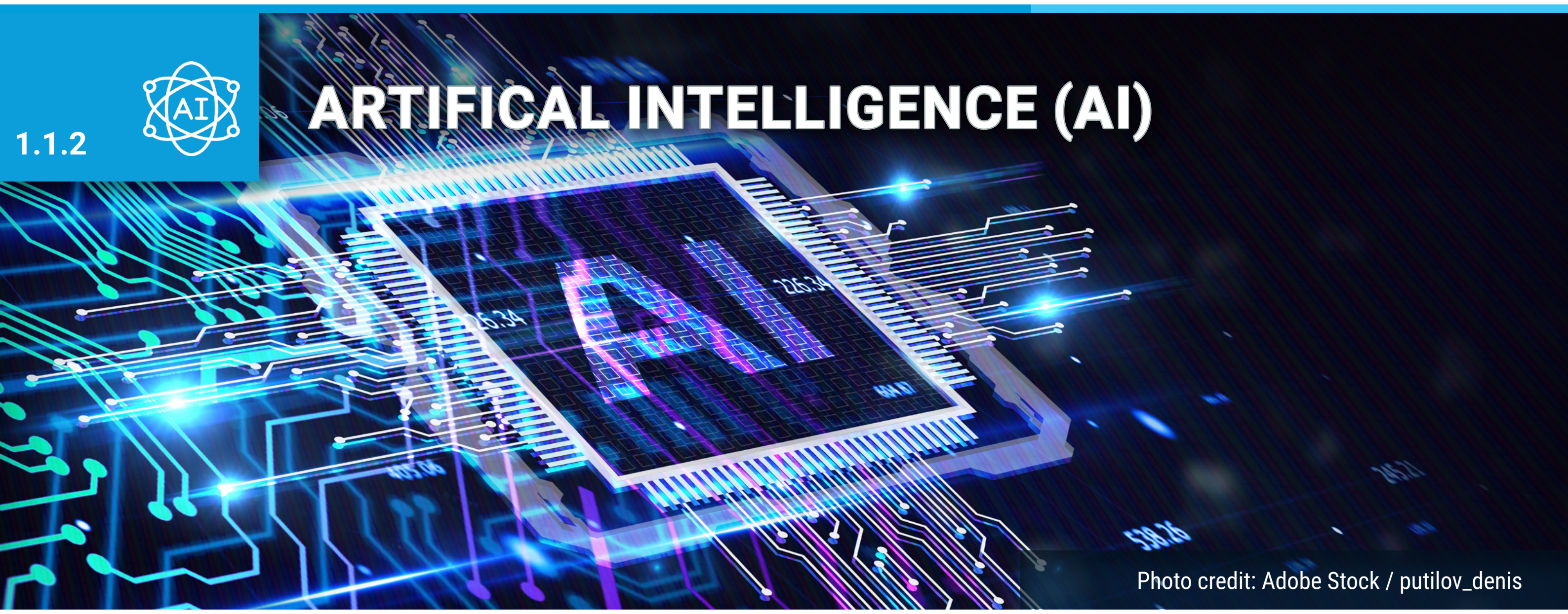
1.1.2

ARTIFICAL INTELLIGENCE (AI)



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What is AI?

Bellman (1978) defined AI as “The automation of activities that we associate with human thinking, activities such as decision-making, problem-solving, learning”. AI can be subdivided into three categories: artificial narrow intelligence (ANI), artificial general intelligence (AGI) and artificial super intelligence (ASI).

Both AGI and ASI refer to the future state of what people expect AI to become: machines that can perform any intellectual human task or even solve seemingly unsolvable problems. ANI fits current standards of AI: technology programmed to achieve one specific purpose or task.

ANI gave rise to the subfield of machine learning (ML)—AI developed to perform tasks through learned experience. ML can be further divided into supervised ML and unsupervised ML. The former uses labelled data (examples of what we want the machine to recognize) to map inputs to outputs. The second uses unlabelled data, which may look like unlabelled or undescribed text or image, from which a deep learning algorithm finds underlying patterns with minimal human supervision. This may be done through natural language processing (NLP), the process through which AI analyses textual data, or computer vision, the process through which AI analyses visual data (images and videos).

AI is seamlessly integrated into diverse technological domains. The following section lists seven present-day applications of AI technology.

1. **Automation:** The use of AI technologies with automation tools can expand the scope and complexity of tasks that these tools can perform. A notable example is robotic process automation (RPA), a type of software that automates routine, rules-based data processing activities traditionally managed by humans. When combined with ML and emergent AI tools, RPA can automate larger segments of tasks within an enterprise, enabling strategic bots to integrate insights from AI and adapt to procedural changes.

2. **Machine learning:** This discipline involves empowering computers to act without explicit programming. Deep learning, a subset of machine learning, is conceptually similar to the mechanization of predictive

analytics. Machine learning encompasses three main types of algorithms:

- Supervised learning: Data sets are labelled, enabling the algorithm to detect patterns that will then enable it to label new data sets.
- Unsupervised learning: Data sets lack labels and are sorted based on inherent similarities or differences.
- Reinforcement learning: Although data sets lack labels, the AI system receives feedback after executing actions, facilitating iterative learning.

3. **Machine vision:** This technology provides machines with visual perception capabilities, allowing them to analyse visual data using cameras, analogue-to-digital conversion and digital signal processing, and machine vision. Unlike human sight, machine vision is non-biological and can be programmed to see through physical barriers, such as walls. It is used in diverse applications, ranging from signature authentication to medical image interpretation. Machine vision is occasionally confused with computer vision, which is machine-based image processing.
4. **Natural language processing (NLP):** This involves the computational processing of human language. An archetypal use of this technology is spam detection, which evaluates email subject lines and text content to determine whether they qualify as junk. Modern approaches to NLP are grounded in ML and include tasks such as text translation, sentiment analysis and speech recognition.
5. **Robotics:** This branch of engineering focuses on the design and manufacture of robots. These mechanical entities are adept at performing tasks that are tedious for humans or require consistent performance. Robots can be used in a wide range of scenarios, from automobile assembly lines to the movement of large objects in space, which NASA is pioneering. The integration of ML has enabled the development of robots capable of interacting in social contexts.
6. **Self-driving cars:** Autonomous vehicles use a combination of computer vision, image recognition and deep learning to acquire the skills necessary to pilot a vehicle without a human driver. This includes staying in designated lanes and avoiding unforeseen obstacles, such as pedestrians.
7. **Text, image, and audio generation:** Generative AI techniques create various media formats based on text prompts and are being used across industries. They produce a wide range of content types, ranging from photorealistic artwork to email responses and screenplay drafts.

AI in disaster management: Use cases

AI can prove helpful in humanitarian settings. For example, in a health crisis, AI can extract, analyse and represent information about the severity of certain health problems, hotspots, potential solutions and misinformation. Microsoft funds numerous projects that integrate AI with humanitarian action. With support from Microsoft, a group known as Seguro has made a chatbot that uses AI to help victims of gender-based violence. SEEDS India used AI to create a system that helps predict the risk of natural disasters based on local conditions, improving preparedness and creating tailored response plans. The Turkish Red Crescent Society has developed software to help reunite Syrian refugees with their families, while the Humanitarian OpenStreetMap Team has designed tools to help identify high-risk areas and enable quicker and more efficient responses to disasters. Centro Legal has developed an AI tool to help people, including refugees, with case management for asylum status, including document translation and management. The Carter Center has devised a tool that can help analyse data to facilitate peacebuilding and help negotiation efforts. There are many other examples.

When applied correctly, AI can improve response times by navigating and processing real-time information and aiding decision-making processes. It can be used to effectively detect disasters before they take place, from which comes a new range of prevention and mitigation techniques.

AI in disaster management: Challenges and opportunities

The use of AI in humanitarian settings raises many of the same challenges that surround its use in general. For example, biased AI can challenge a "do no harm" framework, and the question of who should take responsibility for AI decisions remains unclear. In time-sensitive situations, there may also be an over-reliance on AI outputs and a temptation to interpret AI outputs as truth. To make matters worse, most non-profits and NGOs lack the experience to develop their own AI solutions, so they have to hire outside experts. Non-profits must compete with large corporations for the best human talent. While NGOs are trying to hire more people with expertise, they still lack the proper oversight needed to integrate an AI specialist into an organization effectively. Raising funds to integrate AI is an expensive proposition for donors, as such funds must cover not only hiring expertise, but also maintaining the underlying infrastructure. Another key challenge is sharing confidential information in large language models such as ChatGPT, and the implications of doing so.

Other drawbacks associated with AI technology include:

- **Cost:** The implementation and maintenance of AI systems can be financially demanding.
- **Technical expertise:** Operating AI technology requires high levels of technical proficiency.
- **Skilled workforce deficit:** There is a scarcity of professionals with the skills to build AI tools.
- **Inherent biases:** AI systems can inadvertently perpetuate the biases present in their training data when scaled up.
- **Lack of generalization:** AI's ability to generalize learnings from one task to another can be limited.

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1.1.3

AUGMENTED REALITY AND VIRTUAL REALITY

Photo credit: Unsplash / Eddie Kopp

What are AR and VR?

AR is an interactive technology that seamlessly blends digital elements with the physical world. It is compatible with both mobile and desktop devices. What makes AR unique is its ability to overlay digital components onto the real world, creating a dynamic interplay between the virtual and the tangible. One example of AR that many people are familiar with are filters on social media apps like Snapchat and Instagram. These apps take camera-generated footage and superimpose digital modifications on it.

While AR combines the real and the digital, VR creates immersive environments that are entirely digital. This is most often achieved through a headset that contains a screen that displays an alternate environment that users interact with through pivotal technologies like computer vision, depth tracking and mapping. Cameras capture real-time user data that is then processed so that it can be seamlessly integrated with digital elements. VR environments can be settings for a game, recordings of a real location, or a digital environment to make spending time with other people online more relatable (e.g., a virtual conference, such as those held during Covid-19).

A prominent example of these technologies is the metaverse, an evolving 3D-enabled digital realm that leverages VR, AR and cutting-edge Internet and semiconductor technologies. It aims to enable individuals to participate in immersive personal and business interactions online that are similar to real-life experiences.

To realize the full potential of AR, specialized devices are required. Smart glasses are often used for this purpose, working in conjunction with special software to deliver augmented data to the user.

AR/VR in disaster management: Use cases

There is great potential for AR/VR in humanitarian settings. For example, the technology can be used to improve education, as demonstrated by UNICEF, which reported that VR proved useful for classroom learning in Nigeria. Other applications include educational simulations on disaster relief, which can later help with post-crisis planning and management. VR/AR has also been used for fundraising and information-sharing: a 360-degree camera shot of a disaster setting or hospital can be used to create an immersive experience to help donors or partners better understand the situation on the ground.

When meetings cannot be held in person, as was the case during the Covid-19 pandemic, AR/VR can create a virtual social space while respecting physical social distancing. The US military uses what is known as “tactical AR” to help soldiers in the field learn about their surroundings, distinguish friend from foe and gather personal information. In a humanitarian context, tactical AR could improve search and rescue efforts by providing rescuers with critical information such as infrastructure warnings and the location of trapped people. Similar techniques are already being used to help locate and rescue survivors in smoke-filled environments. AR/VR can also be used in disaster preparedness simulations to enable ground responders to experience such events in a safe and controlled environment. Research has also shown that AR/VR technology can be used to display optimal escape routes from a disaster zone and to overlay disaster-related information using a smartphone camera.

AR/VR in disaster management: Challenges and opportunities

Some of the drawbacks of AR/VR include:

- high implementation costs
- suboptimal device performance with AR applications
- shortfalls in safeguarding user privacy
- potential security breaches

AR/VR currently requires further development to make it more reliable and able to be used for longer periods. Until tactical AR is developed more, its potential for wider adoption is limited. Although AR/VR is currently being used in the humanitarian sector, some of its greatest potential benefits are still to come. For now, due to the cost and niche nature of AR/VR, its main use in the humanitarian sector is likely to be specialized simulation training for humanitarian and development workers.

AR/VR in disaster management: Sources and further reading

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1.1.4

BLOCKCHAIN

Photo credit: Adobe Stock / Elenabsl

What is blockchain?

In essence, blockchain is a type of database. Each entry in this database is known as a block, and each has a unique identifier, a code generated based on the data it contains. Consequently, changing the data in a block also changes this unique identifier. Every subsequent block added to the chain includes a reference to the previous block's unique identifier. These internal references prevent data in the blockchain from being tampered with, as changing any one block will invalidate the reference that the next block attempts to point to, making it easy to discover altered data.

To further prevent tampering, the blockchain is shared among different people, each of whom maintains an identical copy of the database (referred to as a 'ledger'). If someone were to alter one block in the blockchain and then change all the subsequent blocks, the chain would still need to be validated by comparing it to the blockchain held in other ledgers in the network. For a change to a block to be validated, the chains in at least half of the ledgers must also be changed.

Many blockchain networks are open to anyone, creating a decentralized way of tracking information for various purposes. Monitoring financial transactions is one example: blockchain removes the need for a trusted middleman (such as a bank) to handle people's information and money. Instead, transactions are handled directly between individuals themselves.

Blockchain in disaster management: Use cases

The main use case for blockchain in disaster management settings is for response and recovery. It can be used for supply chain management, preproject donor funding processes, cash programming, crowdfunding and to create digital IDs for refugees. For example, a project called Blocks for Transport was launched in Ethiopia to speed up the process of receiving aid trucks from Djibouti. This project allowed verified government documents to be transferred between parties much faster, cutting down on potential corruption. UNICEF is currently supporting a cryptocurrency fund to accept and process crypto-based philanthropy and donations. UNDP

Serbia is even using blockchain to help people send remittances to their families, significantly reducing the cost of transferring this money and tracking its use. Another notable example comes from the Vanuatu Business Resilience Council, a CBi Member Network, which pioneered digital cash for disaster relief in Vanuatu. UNDP Lebanon has a blockchain platform for crowdfunding its projects. One example of digital IDs is a UN Women and WFP project in Jordan, where digital resources for refugees are stored on the blockchain, and refugees can access their resources by scanning their irises at WFP-managed grocery stores.

Blockchain in disaster management: Challenges and opportunities

Some of the key challenges associated with blockchain technology include the following:

- certain blockchain types require significant technology investments
- transaction throughput is limited
- blockchain has a track record of being used for illegal activities, such as on the Deep Web
- the regulatory landscape is uncertain and varies across jurisdictions
- there are limitations relating to data storage capacity

In the humanitarian context, cutting out the middleman can help increase efficiency and transparency. Blockchain thus creates a more transparent system for allocating funds and ensuring that they reach those in need. Blockchain also offers lower transaction fees, shorter transaction times, increased accountability and more traceable information. It offers high data security, which is essential when working on projects such as the UN Women project in Jordan and others involving refugee biodata. Blockchain also increases data sharing between and within systems, facilitates multi-stakeholder partnerships and improves supply chain traceability.

However, due to the highly technical and decentralized nature of blockchain, all participants in a blockchain network must reach a consensus on the data and operating rules, which may be difficult to implement in more diverse contexts. Its use can thus be challenging for computationally advanced processes, as accessing it may be impractical in unstable or disaster-stricken settings or those involving refugees. In addition, the risk of dependence on digital infrastructure could widen the digital divide, and the hidden costs of Internet connectivity, server updates and high energy consumption in post-disaster areas may hinder blockchain implementation. Finally, there was still no legal framework for blockchain at the time of writing.

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1.1.5

CLOUD (COMPUTING) TECHNOLOGY

Photo credit: Adobe Stock / Thitichaya

What is cloud computing?

Cloud computing is a broad concept that can be roughly described as the remote delivery of computing services over the Internet. In other words, the machine processing the services does not need to be on-site. Cloud computing has reached almost all areas of society and takes a variety of forms, including specific services. Infrastructure as a Service (IaaS) provides users with a space to develop and manage software applications, along with backend logistics. Platform as a Service (PaaS) enables users to build applications themselves on the service provider's platform. Finally, Software as a Service (SaaS) is a business model that allows users to access software applications online.

Five conditions are commonly used to define whether a service constitutes cloud computing:

- On-demand self-service: the user can access the cloud without a cloud host's involvement.
- Broad network access: users can access the service in a variety of ways, such as web browsers or mobile phones.
- Resource pooling: multiple users can share resources on one or more systems simultaneously.
- Rapid elasticity: the resources can be scaled up and down to meet user demand.
- Measured service: the provider monitors usage to optimize its services.

Cloud computing for disaster management: Use cases

After a disaster, cloud computing can enable business continuity from alternate locations. In addition, the technology offers improved management, storage, sharing and processing of data for humanitarian teams remotely and on the ground. It enables large data sets to be processed more quickly in the cloud using ML algorithms, without on-site equipment. GIS is another common application: cloud computing allows only the data collection equipment and experts to be physically present in the field. The data they collect can then be processed remotely, thus guaranteeing the kind of working conditions often unavailable in humanitarian settings, such as clean, cold environments, extended access to electricity and other conditions that reduce the risk of damage to equipment.

In essence, cloud computing provides remote field workers with the same level of computing power as if they were on-site. It is already being widely employed in crisis contexts, such as to facilitate 3D printing at hospitals. Another example is the cloud-computing-enabled GeoPhoenix platform, which uses GIS to help responders track emergency vehicles. And during the pandemic, cloud computing was used to bring education to children's homes during lockdowns.

Cloud computing for disaster management: Challenges and Opportunities

Some of the challenges associated with cloud computing include:

- Data security and privacy: Cloud computing raises data security and privacy concerns by entrusting sensitive information to third-party providers that may not have robust safeguards in place, which can lead to unauthorized access, breaches and leaks. Compliance risks arise when regulations such as GDPR or HIPAA must be followed.

- Reduced visibility and control: Cloud users lack complete visibility into how providers are managing, configuring and optimizing their cloud resources. Customization and modification of services is limited, impacting the ability to meet user needs.

- Complexity and opacity: Understanding intricate cloud technologies and their interconnections is challenging, given their scale and complexity. Achieving control and agency within these systems requires understanding, even if complete understanding is unattainable.

- Cloud migration challenges: Cloud migration involves transferring data, applications or workloads between cloud environments or uploading them to the cloud from on-site set-ups. This process can be complex, time-consuming and costly. Compatibility issues between different cloud platforms or architectures can arise, resulting in downtime, performance issues or data loss if the migration is planned and executed appropriately.

In a disaster management context, cloud computing supports other technologies. However, without an Internet connection, synchronization with the cloud is not possible and only locally saved data is available. Provided that Internet access is available, cloud computing can support real-time data collection at a low cost, giving workers in the field access to more computing power and tools without upgrading local equipment and thus improving collaboration among disaster response stakeholders. The use of cloud services also eliminates the need for personnel to store sensitive data and information on physical devices in locations where those devices may be confiscated or searched.

Privacy and security concerns are heightened in humanitarian settings because the data involved is often considered sensitive and requires greater protection for vulnerable populations. In the United States, the Clarifying Lawful Overseas Use of Data (CLOUD) Act amended the Stored Communications Act to specify that an electronic communications service or remote computing service provider must comply with existing requirements to preserve, back up or disclose the content of an electronic communication or non-content records or information relating to a customer or subscriber, regardless of whether the communication or record is located inside or outside the country. For example, organizations must comply with national laws when transferring data abroad. As a result, there is a need for frameworks that enable these matters to be handled securely. Stakeholders are often unaware of the importance, implications and consequences of not following these procedures, so it is also important to address this concern at the same time.

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1.1.6 5G COMMUNICATION NETWORKS AND 5G

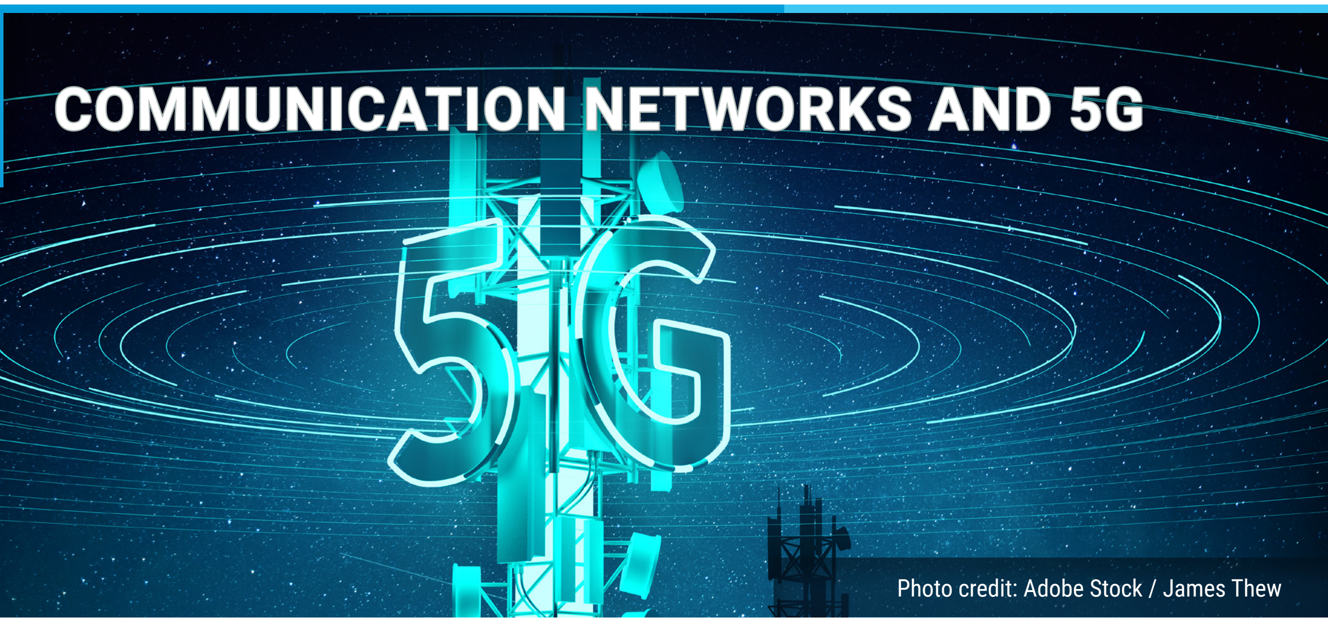
Photo credit: Adobe Stock / James Thew

What are communication networks and 5G?

Communication networks concern the flow of messages between communicators (nodes) and the underlying architecture that enables this flow. Messages can include data and images — anything that can move from one node in a network to another. While there are many types of networks, this section will focus primarily on cellular networks. A cellular or mobile network allows mobile phones to make calls, send and receive messages and receive data. Cellular networks use radio waves to communicate and are distributed over land areas called cells, each of which is served by at least one fixed-location signal distributor known as a cell site or base station. Cell sites and base stations are typically cellular towers: tall structures with a large number of antennae.

Cellular networks have been divided into generations as the technology underlying them has evolved, namely 1G (first generation), 2G, 3G, 4G and 5G. The main factors distinguishing between generations are speed, latency and bandwidth. Speed is the rate at which (Internet) data can be downloaded or uploaded, latency is the time it takes for a signal to be sent and a response to be received, and bandwidth refers to the frequencies of radio signals used by the network.

In line with SDG 9 (which emphasizes building resilient infrastructure, promoting inclusive and sustainable industrialization and fostering innovation), 5G technology enables data to be collected and used in new ways, using key technologies such as big data, AR and deep learning. The development of these technologies contributes to significant socioeconomic progress.

Communication networks and 5G in disaster management: Use cases

Scaling up 5G networks is a significant challenge that can be sidestepped by setting up smaller, localized networks instead. For example, if there are several locations with a 5G network as opposed to general 5G coverage, humanitarian response teams can run operations from these zones. This can help teams process and move more data than would otherwise be possible.

Many countries have early warning systems that use communication networks to inform the population immediately. When communication networks become unavailable, solutions such as THOR mobile can be used, brining ultra-wideband 5G in a response vehicle to any location. THOR can be used to create a mobile network, a control centre for drones and other computing solutions. An alternative example is Starlink, which provides a satellite-based Internet connection that does not require on-the-ground infrastructure.

Communication networks and 5G in disaster management: Challenges and opportunities

As mentioned above, 5G is not currently accessible in all countries. However, 3G and 4G networks remain viable options for disaster management. Other communication networks such as radio and the Internet are also important, particularly when cellular networks fail. In addition, while 5G is useful for devices like robots and drones, its short range can be a hindrance for activities like search and rescue, as walls and glass can interrupt the network, limiting the number of people who can be located under rubble.

Other challenges and considerations related to 5G include:

- Infrastructure gaps and universal coverage: Not all countries or regions have access to reliable 4G and 5G technology. 5G population coverage varies from 16 per cent in Asia-Pacific to 36 per cent in the Americas and 52 per cent in Europe. Similarly, data from the International Telecommunications Union (ITU) on 4G network availability shows significant differences between Europe (94 per cent) and Africa (7 per cent). The gaps are wider for fixed broadband than for mobile data. Expanding 5G coverage will require addressing these existing gaps in telecom infrastructure, especially in areas where previous standards have not been reached. Deploying mobile networks for 5G requires less investment than fixed broadband networks.

- Costs and infrastructure expansion: The expansion of 5G networks can build on existing infrastructure, repurposing 3G and 4G antennae and site permits to reduce the investment required. Widespread 5G coverage will require additional antennae and microcells on existing sites. The GSM Association predicts that the number of sites per operator will increase from 20–30 to 50 by 2025, with potential cost savings from leveraging existing 4G assets.

- Private sector innovation: Operators are forming network-sharing agreements to reduce deployment costs, especially in new service areas. Global technology leaders such as Google are investing in physical infrastructure, submarine cables, cloud services and content delivery networks. Neutral operators with wholesale business models are investing in infrastructure development and cost-sharing.

- Government support and regulatory policies: Government support is critical to the availability and development of the 5G spectrum. Regulations that encourage shared deployment and reduce duplication of resources can lower barriers. Installing antennae in public buildings and streamlining administrative processes for private property placement should be facilitated. Spectrum regulation, auctions and deployment incentives can be used to reduce acquisition costs and encourage faster deployment. Some countries are allocating part of their spectrum to new entities, private companies or non-traditional operators.

- Lessons from deployment experience: Collaborative models and public intervention can support cost-effective deployment and coordination. Tailored approaches are essential due to different country-specific factors. Opportunities exist to improve connectivity and maximize the value of 5G through improved availability.

Communication networks and 5G in disaster management: Sources and further reading

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1.1.7 CROWDSOURCING


Photo credit: Adobe Stock / Gunayaliyeva

What is crowdsourcing?

Crowdsourcing brings together the collective intelligence and resources of multiple actors to serve a common goal, usually through online platforms. The aim is to get a group of people to contribute towards a cause in some way, often to achieve social good. Crowdsourcing/funding projects typically involve profit sourcing, online communities, large group participation, knowledge-sharing and self-governance. Another distinguishing feature of this approach is that it relies on volunteers and is not legally binding.

Crowdsourcing in disaster management: Use cases

Crowdsourcing is used for geotechnology (collecting geographic information), mobile communication, digital crisis information (gathering, sharing and using crisis-related information), digital volunteering, collective intelligence, multi-directional communication and situational awareness. Crowdsourcing is fundamental to humanitarian fundraising. For disaster preparedness, crowdsourcing can be used to bring together volunteers willing to analyse information through a platform such as the Colorado Virtual Warehouse. In disaster response, crowdsourcing via social media and mobile SMS can help spread information and establish communication methods. Likewise, smartphones with accelerometers have been crowdsourced to detect, locate and measure earthquake activity. For disaster recovery, victims can crowdsource data and images on their losses to help illustrate the extent of the damage. For disaster resilience, crowdsourcing can be used to provide resilience-building training.

The most cited use of crowdsourcing in disaster response is Mission 4636 following the 2010 Haiti earthquake. Haitians needing help could text this new emergency response number, and volunteers all over the world translated, mapped, forwarded and responded to their needs and requests for help and information within five minutes. Volunteers also created up-to-date working road maps and camp maps for displaced people, gathering accurate data for the entire country in just two weeks.

Crowdsourcing for disaster management: Challenges and opportunities

Crowdsourcing is relatively cheap to implement and can be the easiest way to obtain information in a disaster situation. It can increase the sense of trust and ownership within a population and help communities cope, as trust among citizens is positively correlated with collective efforts to prevent risk. However, crowdsourcing is challenging without access to platforms: for people to contribute, they need access to data services, mobile networks and cell phones and/or smartphones.

Another concern is data privacy and management. Data may need to be anonymized to protect privacy, which is difficult to ensure during a disaster, when images of victims and property are often used for response and recovery efforts. In addition, crowdsourced data should ideally be vetted for bias and fact-checked before being used for modelling and situation reporting. If errors are made, it is difficult to assign responsibility.

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1.1.8

CYBER-PHYSICAL SYSTEMS

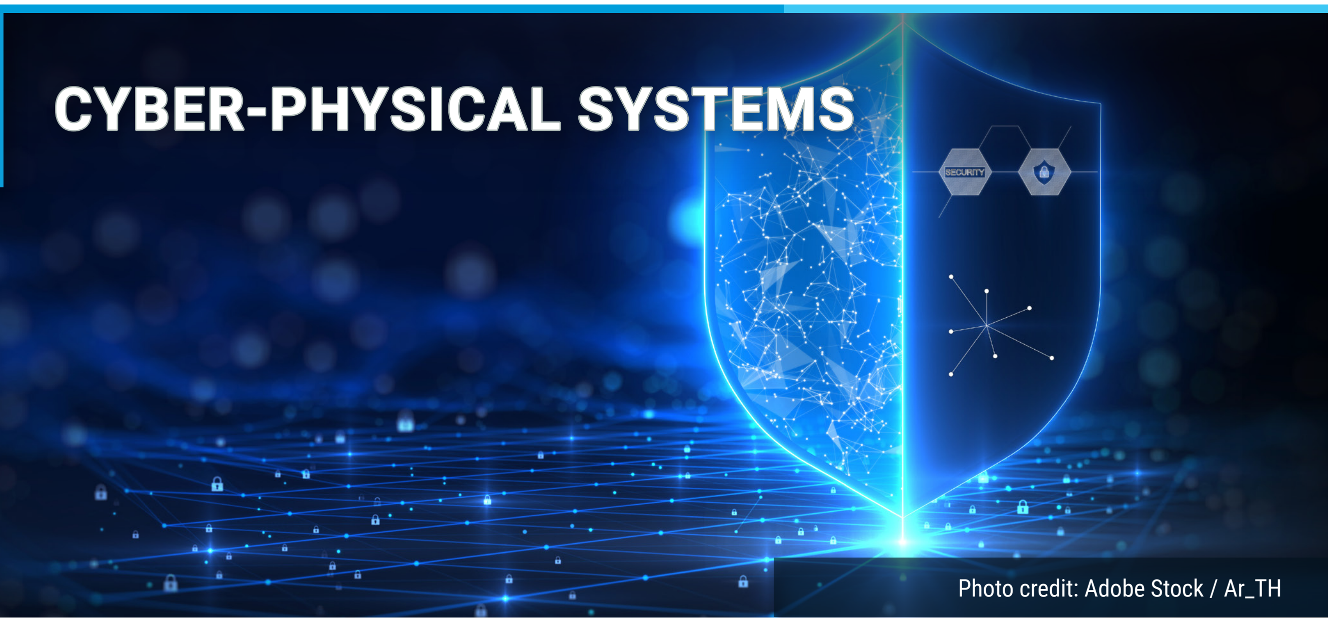

Photo credit: Adobe Stock / Ar_TH

What are cyberphysical systems?

Cyberphysical systems (CPSs) integrate physical and digital computational systems. For example, when a drone operator instructs a drone to fly, the drone has sensors, such as gyroscopes, that enable it to process information about the surrounding world, which it then adjusts to. For instance, weather or other adverse conditions may disrupt the drone's ability to fly as instructed, so the drone calculates adjustments to remain stable. In other words, CPSs are systems that can adjust their component systems to achieve the desired goal by digitally computing information from the outside world.

Cyberphysical systems in disaster management: Use cases

CPSs make technologies more effective in disaster management. As well as being an integral part of drone technology, as described above, CPSs enable 3D printers to function. IoT is another direct implementation of CPSs, as it connects devices using various sensors and protocols. CPSs can help with disaster preparedness and mitigation by integrating technologies for purposes such as forecasting storms and water levels and running simulations. CPSs are essential to the autonomous robotic systems used for search and rescue operations during disasters. These robots can navigate treacherous terrain, locate survivors and transmit critical data to response teams, increasing the effectiveness of disaster response efforts.

Cyberphysical systems in disaster management: Challenges and opportunities

Security challenges include:

- Security issues: Many CPSs are not secure because they are isolated from networks such as the Internet and rely heavily on physical security measures. Cyberphysical security is also a challenge. CPSs need to move to a holistic approach to security that encompasses both cyber and physical aspects to improve protection against future cyberattacks with physical consequences. People affected by disasters are often vulnerable, making it even more important to ensure that their privacy is protected when using CPSs, especially if the system in question is vulnerable to hacking.

- Real-time requirements: This vulnerability underscores the urgency of immediate and timely responses in CPS applications within disaster management scenarios. Swift decision-making is crucial in CPS systems facing network attacks. In such situations, the ability to respond promptly is paramount to ensuring the system's readiness and effectiveness. Timely responses are vital for adapting to evolving threats, making swift decisions, and safeguarding the integrity and functionality of CPSs during critical disaster situations.

- Coordinating change: The roles and rights of various CPS stakeholders need to be carefully managed, as do changes during transitions.

- Infrastructure factors: Technologies using CPS that require strong technological infrastructure are potentially problematic. The required infrastructure may not exist in disaster contexts, and even if it does, it may be susceptible to damage.

Thus, while CPSs may prove useful in the disaster management cycle, investment is required to ensure that the region where it is intended to be used meets the criteria for its adoption.

CPSs in disaster management: Sources and further reading

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1.1.9

DRONES

Photo credit: UNDP DRC / Aude Rossignol

What are drones?

The term “drone” is often used to refer to unmanned aerial vehicles (UAVs), although a drone does not necessarily have to fly — remote-controlled spider robots or submarines are also drones. However, this section will focus exclusively on UAVs, which range in size from tiny devices to the Boeing Odysseus, which has a wingspan of 74 metres. There are three main types of UAV: fixed wing (manoeuvring like planes); rotary (manoeuvring like helicopters); or hybrid (a combination of the two). Drones can be equipped with cameras, meteorological or infrared sensors or deliverable goods, meaning that they can be used in a wide range of sectors.

Drones in disaster management: Use cases

Drones can also be used in a variety of ways in disaster contexts. For example, drones carrying cameras can be used to create highly detailed maps of areas vulnerable to meteorological hazards or to identify faulty infrastructure. The data collected can then be used for disaster preparedness. This can be done in a matter of hours to months, depending on the size of the area. Drones can be used for rapid damage assessment, allowing humanitarian and development workers to quickly inspect infrastructure without risking human lives, and infrared cameras can detect trapped bodies during search and rescue missions. Drones can also be used to deliver emergency supplies to people who would otherwise be difficult to reach. During disaster response, drones can provide up-to-date information about the affected area in a time- and cost-effective manner. Stakeholders can gain a better understanding of the situation on the ground, enabling better communication, collaboration and strategic decision-making.

Drones in disaster management: Challenges and opportunities

Drones rely on electricity, so charging them in humanitarian settings may be difficult or impossible. Any data collected must be handled carefully, ethically and safely to avoid exacerbating vulnerabilities. The lack of an international law or regulations on drone use makes their global adoption in humanitarian and development settings difficult, although some countries have detailed regulations on flying drones that require special permits. Consequently, the sector needs a paradigm shift to enable drones to be used effectively. Existing protocols and procedures must be redesigned, staff need to be trained and new methodological frameworks need to be created for their use. The Humanitarian UAV Code of Conduct aims to address this by promoting ethical, responsible and safe use of drones across disaster management contexts. Lastly, the novelty of drone technology means there is a general gap in technical knowledge for their use in disaster management contexts.

Drones in disaster management: Sources and further reading

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1.1.10

GEOGRAPHIC INFORMATION SYSTEMS (GIS)

Photo credit: Unsplash / Valerie V

What are GISs?

A GIS captures, stores, analyses, manages and presents various types of geographic data. GIS use multilayered maps to display spatial information such as elevation, meteorological data, resources, man-made structures, mass migration and demographic data. These systems combine computer science, geodesy, geomatics, geography, statistics and ML. GIS software tools can be used on any computer with sufficient processing power. They often draw on data from remote sensing systems such as satellites, airplanes or drone imagery. Traditional storage or cloud computing solutions can be used to store and process this data.

GIS in disaster management: Use cases

No expertise is needed to read or interpret GIS maps, and there are many applications for them in humanitarian settings. For example, they have proved useful for mapping, managing and analysing disease outbreaks, as well as for identifying high-risk areas, analysing how diseases will spread and assessing how outbreaks can be prevented from escalating.

GIS can also be used to locate high-risk and disaster-prone areas for disaster preparedness and mitigation efforts. Their applications include modelling how disasters will spread and creating evacuation routes and local response protocols. During the response and recovery cycles, GIS can be used to create up-to-date area maps, support damage assessments, identify high-need areas and flag obstacles.

The United Nations Satellite Centre (UNOSAT) hosts e-learning courses and produces high-quality maps that NGOs, governments and organizations can use in areas such as development, humanitarian response, policymaking and climate action. A practical example is the University of Hawaii's Pacific Disaster Center GIS platform, which displays global hazards such as tornadoes, conflicts, terrorism, disease outbreaks and earthquakes in real time.

GIS in disaster management: Challenges and opportunities

GIS are an asset to humanitarian organizations because they integrate multiple data sources. This means, for example, that the locations of floods and shelter facilities can be analysed simultaneously. The main challenge is the availability and quality of the data needed to create these systems. For example, when data is collected by satellite remote sensing, cloud cover can prevent a clear view, leading to delays in disaster response. Drones could be an alternative way of collecting such data, although there are legal hurdles to their use, as mentioned above.

GIS in disaster management: Sources and further reading

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1.1.11

INTERNET OF THINGS (IOT)

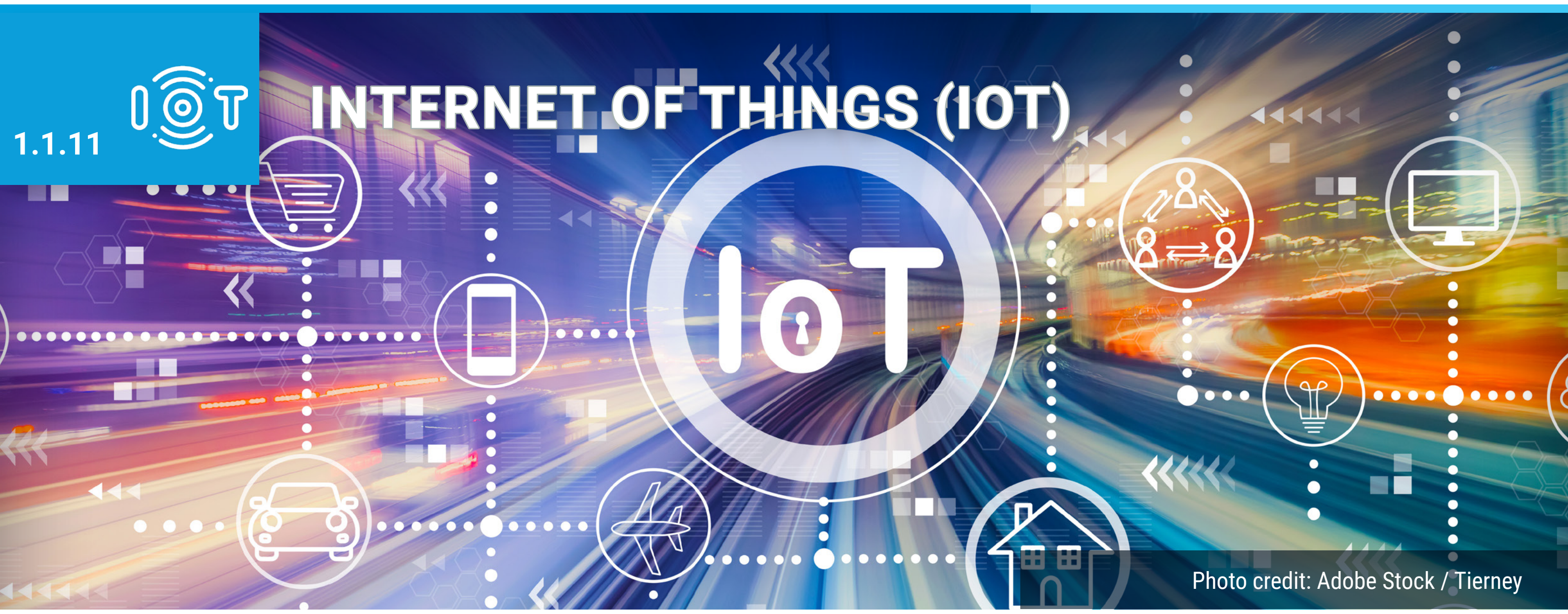

Photo credit: Adobe Stock / Tierney

What is the IoT?

The IoT is an interconnected network of devices and sensors that uses technology to integrate systems, environments and contexts better. A typical modern example of this technology in use is the smart home, which manages domestic lighting, heating, irrigation systems and appliances using timers or humidity sensors. This approach to coordinating technologies can be used for urban planning, to collect data from infrastructure or for automatization and analytics by incorporating AI. The most common way for IoT to work is over the Internet, using cables, Wi-Fi, 4G/5G networks or Bluetooth. IoT interacts with the environment through enablers such as RFID (radio frequency identification), barcodes, QR codes and sensors. These can be used to track temperature, air pollution, light levels, altitude, gyroscopic rotation, the presence of magnetic fields, humidity, sound or motion. Certain devices can then be activated or deactivated based on the readings from these sensors.

IoT in disaster management: Use cases

IoT technology can support every stage in the disaster management cycle. It can enable early warning systems for disaster preparedness by collecting real-time data and connecting data sources/sensors for informed decision-making. For example, it can trigger early warning systems for earthquakes by using sensors that detect vibrations in the ground. During the response phase, GPS sensors attached to vehicles or personnel can be used to keep track of them. Smart warehouses using IoT can automatically monitor inventory, while other IoT technology tracks resource distribution. During the recovery phase, IoT can be used to broadcast information and assess post-disaster conditions, such as by monitoring patients’ medical status, tracking critical resources or collecting information about the aid available in an area.

IoT integration in disaster management provides large data sets for each stage of the disaster cycle, which can later be used to improve situational awareness or response efforts. Through data sharing, IoT can increase organizational collaboration and data accuracy by drawing on multiple sources.

IoT for disaster management: Challenges and opportunities

There are numerous challenges to integrating IoT into disaster management. As with many of the technologies discussed above, privacy concerns are a challenge, as IoT could potentially infringe on people's privacy, posing ethical and legal problems.

Like many modern technologies, IoT relies on infrastructure such as electricity and the Internet. In contexts where access to these is limited or costly, implementing IoT is largely unfeasible. Even when such infrastructure is in place, it is often vulnerable to damage during and after a disaster. While this is not especially problematic for early warning systems, it may jeopardize the effectiveness of systems like smart warehouses, which need to have fail-safes in place to offset any potential damage. It is also advisable to use IoT in combination with other technological solutions to avoid total reliance on a resource that may become unavailable during an emergency. Furthermore, if the IoT systems themselves are damaged, it could lead to broken sensors and faulty readings.

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1.1.12

REMOTE SENSING

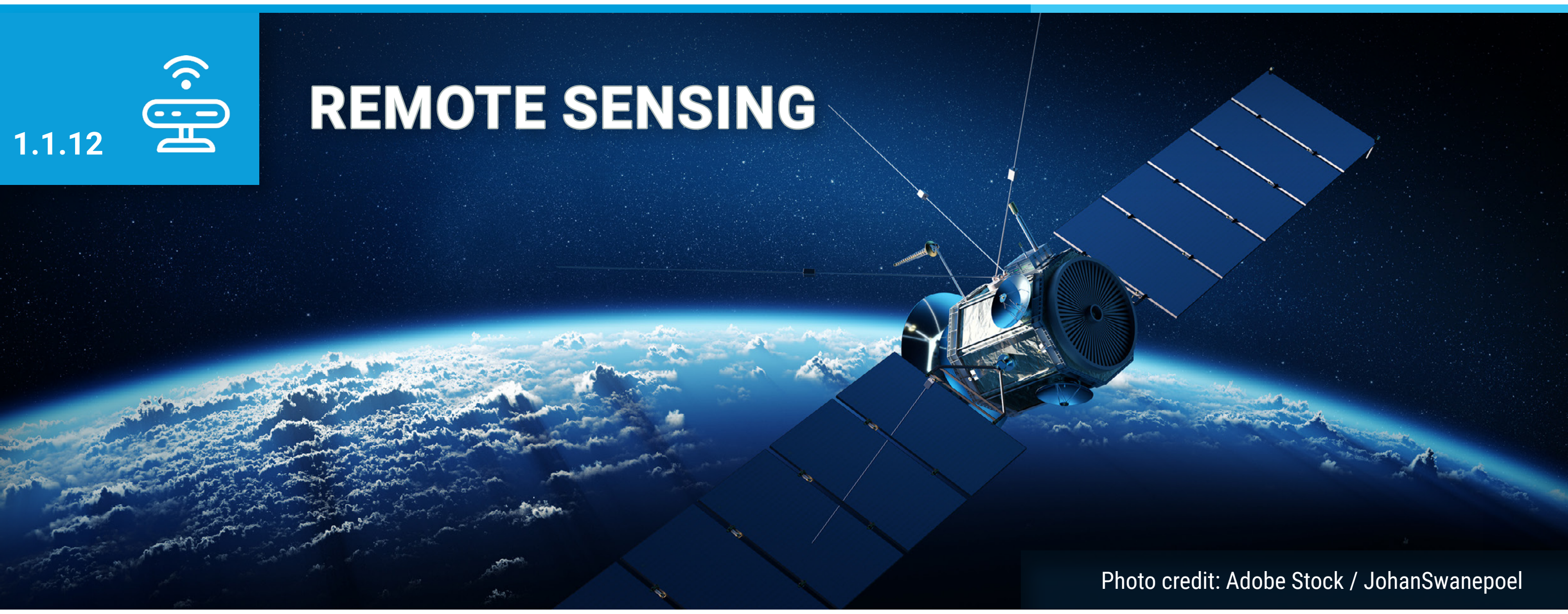
Photo credit: Adobe Stock / JohanSwanepoel

What is remote sensing?

Remote sensing is essentially collecting data from a distance, often by measuring reflected and emitted radiation. This data can be used for many purposes, ranging from GIS applications GIS to IoT integration.

There are two methods of remote sensing: passive and active. In passive remote sensing, the sensing device merely detects and captures information from the target object or area, such as the radiation it is emitting or reflecting. In active remote sensing, the device itself emits energy to enable the sensors to capture what the user wants to observe. For example, if there is not enough light to collect data, the sensor will generate the light needed to collect that data.

Remote sensing for disaster management: Use cases

Remote sensing can be used to track storms and predict the weather. Knowing what path a storm will take or what kind of extreme weather a region can expect is vital in preparing for potential disasters. Remote sensing can also be used to predict floods and assess vulnerability before a disaster happens by creating land elevation maps. This can be applied to disaster response. For example, remote sensing can be used to map the location and severity of damage, and to monitor forest fires, floods, volcanic eruptions and dust storms.

Remote sensing can also be used in the recovery phase to assess flood, fire and infrastructure damage and monitor recovery efforts. It offers a way to monitor said issues in a safe, and time-efficient manner because the data is collected from a significant distance, using satellites or infrared sensors, for example. One advantage of the method is that it can be used in both urban and rural locations.

Remote sensing for disaster management: Challenges and opportunities

Remote sensing satellite imagery is only available on clear days with little or no cloud cover. In addition, the satellite in question must be over the area to be able to collect data. Consequently, remote sensing may not always be the fastest method of data collection for disaster management. As with GIS systems, drones with remote sensing devices can be an effective alternative to satellites, but their practicality may be reduced if they are restricted by cautious legislation. In these circumstances, practitioners may resort to aerial remote sensing, a more costly solution requiring planes or helicopters. Regardless of whether the chosen approach entails satellites, drones or aerial sensing, a certain level of expertise is required, which can be a limiting factor if local stakeholders do not have access to it.

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1.1.13

SOCIAL MEDIA

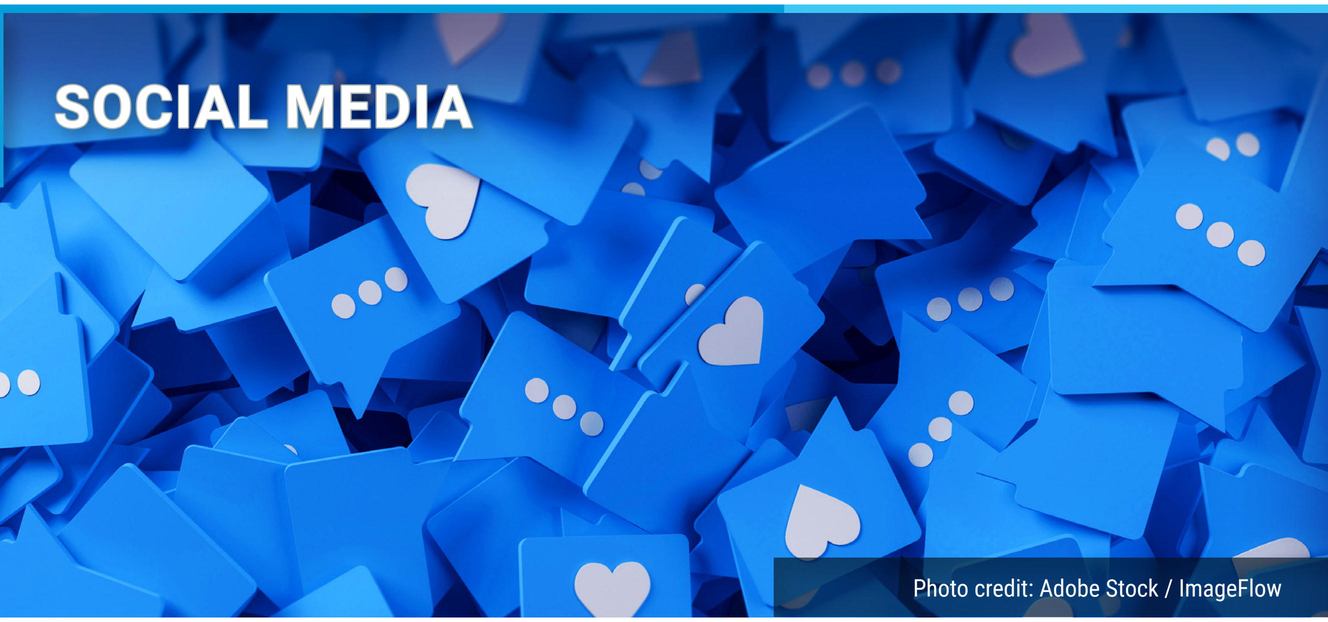

Photo credit: Adobe Stock / ImageFlow

What is social media?

Social media is any technology that connects people's ideas and information through the Internet. It is an inherently casual social environment that is online. Social media platforms play a pivotal role in facilitating information-sharing during crisis management. They provide real-time channels through which individuals, organizations and government agencies can broadcast critical updates, warnings and instructions to a wide audience. The widespread use of social media increases the reach and speed of information distribution, enabling rapid response in emergencies. In addition, user-generated content on social media is a valuable source of first-hand accounts, images and videos that contribute to a comprehensive understanding of the scope and impact of a particular crisis. Collaboration and engagement on these platforms foster a sense of community involvement, allowing users to share resources, offer assistance and coordinate relief efforts. Overall, the immediacy, interconnectedness and user-driven nature of social media make it a critical tool for effective communication and response during crises.

Social media in disaster management: Use cases

The applications of social media in disaster management include information gathering, semi-journalistic verification and crowdfunding. Social media has become a vital tool for gathering information by enabling anyone to share messages, photos and videos across the globe instantly. For example, Twitter's disaster alerts have made the platform useful for emergency communication. Likewise, Facebook has a safety check feature that allows users to indicate that they are safe during a disaster that has affected their location, and Telegram also provides channels for sharing disaster-specific information.

Social media allows organizations to receive the latest news from media and individuals, allowing anyone to voice a problem to the world. It makes it easier to create partnerships, connections and networks. These factors benefit crowdsourcing by enabling large groups of people with similar goals to connect and recruit other like-minded individuals.

Social media for disaster management: Challenges and opportunities

Social media provides relatively unfiltered, real-time information about all kinds of events. This data is often essential for fast and efficient disaster response and helps create a dialogue between emergency response organizations and the public, which in turn builds trust. However, the theoretical and computational process of transforming vast amounts of unstructured, unsupervised data into actionable information remains a major challenge. For example, verifying information to prevent the proliferation of inaccurate data is essential to prevent limited resources from being wasted. Processing this data also requires sound technical knowledge and an understanding of the algorithms these platforms use.

In addition, data processing, protection and anonymization must be rigorous to safeguard the privacy and integrity of data. This is especially true in countries where freedom of speech and the press are limited, and raising issues on social media can lead to repercussions. Conversely, social media is an easy, efficient way for organizations to provide affected populations with up-to-date information during a disaster. It can also be used as a communication network when other forms of communication are limited.

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1.2. USE OF TECHNOLOGIES IN DISASTER MANAGEMENT

1.2.1 Disaster assessment/prediction and early warning systems

Background

A major application of disaster preparedness technologies is disaster forecasting. Historical data sets are used to create models that can indicate the probability of a disaster occurring. Employing such a model and combining it with early warning systems[1] can be a powerful tool for taking timely action in the face of a catastrophic event. As such, disaster prediction and early warning systems are typically part of the same technology stack.

Natural hazards are the main field of application for disaster prediction technologies and early warning systems, because physical and natural phenomena are relatively easier to monitor and are less prone to sudden changes than social ones. The performance of predictive models depends heavily on the quality of the data they use, so the collection, processing and sharing of data play an important role in disaster prediction and the functioning of early warning systems.

Key technologies

Remote sensing, ML, GIS or drones can be used to collect and process data. AI is used for modelling, usually through deep learning. Predictive modelling is a form of AI that uses data mining and probability to forecast or estimate more granular, specific outcomes. Predictive analytics models evaluate historical data, uncover patterns and analyse trends. Predictive modelling aims to predict future events or outcomes by analysing patterns in a given set of input data. The focus of early warning systems is spreading information, so they benefit from existing communication networks, new advancements such as 5G and social media platforms.

Background risk assessment

The aim of risk assessments is to predict disasters and assess the resulting risk to people and the environment. They seek to provide an initial information base that identifies vulnerable groups, assets and areas where resources and efforts should be directed. This information base can be used for decision-making and to help practitioners prepare for disasters more effectively. Situational simulation is commonly used to understand worst- and best-case scenarios. The goal is to move from simply predicting a threshold to a more complex assessment of potential impacts.

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[1] Early warning systems have domain-specific definitions. In the humanitarian context, they describe systems that are used for emergency population warnings to provide time to prepare and respond to a disaster, thus mitigating the impact. For a discussion, see Waidyanatha (2010).

Use of key disaster prediction technologies

Disaster prediction is also used in fragile and conflict settings. Predictive analytics leverage social media data by analysing texts containing the individual reactions, emotions and sentiments of a broad group of different people towards a given issue. Modern ML algorithms can process this information and provide aggregated results that can be used for purposes such as predicting the likelihood of mass migration based on variable data collected over time (Nyoni, 2017). Earlier applications of disaster prediction technologies attempted to predict the spread of diseases such as influenza, dengue or AIDS (Woolhouse, 2011; CDC, 2023). During the Covid-19 pandemic, the ability to estimate how quickly and where the disease would spread, combined with an effective early warning systems, helped people prepare for and mitigate risks (Lin, Liu and Chiu, 2020).

CASE STUDY

Google Disaster Alerts

Google has various initiatives focused on early warning systems, such as Google Disaster Alerts, a mobile phone application that informs users about disasters before damage occurs, providing actionable information on how to stay safe. Beyond that, in a collaboration between various Google teams and external partners around flood forecasting, one initiative focused on India and Bangladesh had a reach of over 250 million people in terms of early warning messages (Nevo, 2020).

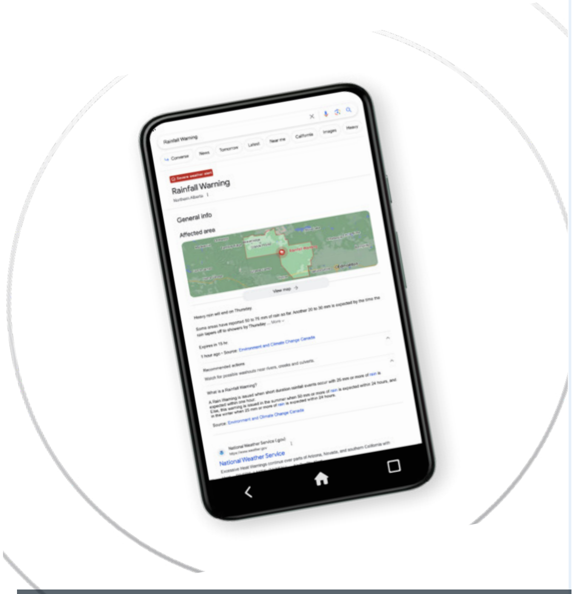


Photo credit: Google Crisis Response

1.2.2 Event simulation

Background

Event simulation falls within the disaster preparedness cycle. The primary objective is to simulate an event that may occur during a disaster in order to prepare and train people. Event simulation attempts to provide an artificial environment in which people can practice and learn how to respond to extraordinary situations safely.

Key technologies

The key technologies for event simulation are AR and VR, but their relative newness means that there is not much experience to draw upon. AR is used to modify specific components of a given environment, which is typically done for technical and medical operations. People can be trained or assisted in real time to perform difficult repairs on critical machines or infrastructure, reducing the risk of human error and the time required for such tasks during a disaster. Similarly, AR is widely used to train and assist medical personnel during operations, reducing risk and increasing response time. AR can also be used to introduce event simulations to the local population, increasing their experience of adverse advents, building their skills and thus increasing local resilience.

VR is used to make catastrophic events tangible through simulation, as an alternative to tabletop exercises and real-life drills. It is mainly used to train emergency responders to navigate disasters quickly and safely. The goal is to provide a realistic experience and prepare responders both mentally and practically for a specific disaster event.

CASE STUDY

Mobile Learning Hub Philippines

In early 2021, the local government of Muntinlupa introduced the Mobile Learning Hub, a VR-powered bus that aims to raise disaster awareness and teach disaster resilience to citizens (De Guzman Quadra, 2020). Through visual and audio experiences, the technology aimed to mainstream disaster preparedness among vulnerable groups and communities while raising awareness on the importance of disaster risk reduction and climate change mitigation and adaptation.

Photo credit: Muntinlupa City LGU

1.2.3 Disaster detection

Background

Disaster detection is part of the preparedness and response cycle. When timely disaster prediction fails, it is critical to detect the occurrence of a disaster as soon as possible. This includes detecting the event, pinpointing its location and informing all relevant parties, such as emergency responders and analysts. It also includes the detection of subevents following the initial disaster, such as infrastructure collapse, fires or aftershocks. There is a positive correlation between the time that has elapsed since the disaster and the success of the response: the first 72 hours are critical to saving lives (World Food Programme, 2018) .

Key technologies

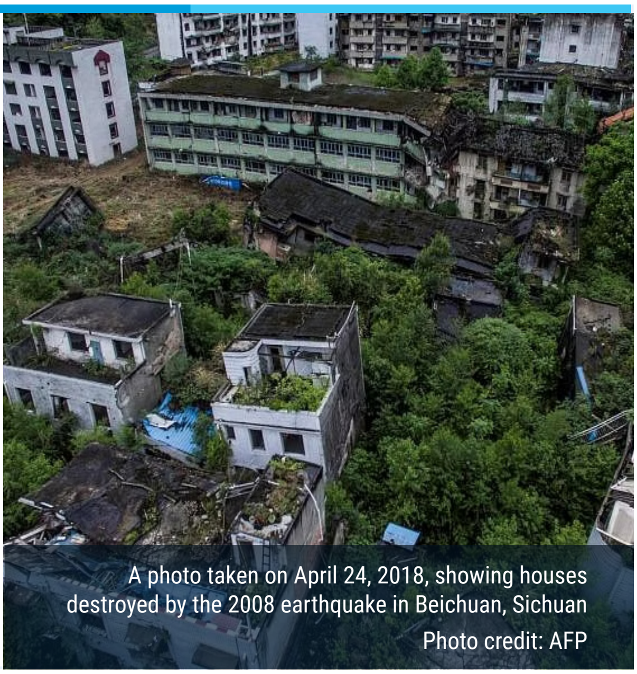
Technology can dramatically improve the efficiency and accuracy of disaster detection and response times. AI and ML can be used to automate and refine the collection, processing, and extraction of data from disaster events to identify specific triggers, such as unusual patterns in seismic activity, sudden changes in weather conditions, or atypical social media activity related to emergency situations, and provide the appropriate parties with real-time information. GIS and remote sensing technology can further support information collection, and IoT is also being used to connect these sensors and provide real-time information about disasters.

With increasing user numbers, social media platforms have proven to be an important source of information and means of communication during disasters. The information may be in the form of images uploaded by users and then classified by ML algorithms or raw text containing information that can be identified using NLP (Ahmad et al., 2019).

CASE STUDY

Earthquake detection through Twitter

The US Geological Survey (USGS) actively uses Twitter to detect earthquakes and earthquake aftershocks. After the 2008 Sichuan earthquake, analysts found that Twitter detected the event up to 60 seconds faster than USGS sensors. As a result, the USGS began incorporating social media analysis into its workflow, including Twitter-based disaster detection in seismic algorithms (Twitter, 2015).



A photo taken on April 24, 2018, showing houses destroyed by the 2008 earthquake in Beichuan, Sichuan
Photo credit: AFP

1.2.4 Search and rescue

Background

Search and rescue is the process of locating and recovering people who are trapped or injured after a disaster. It entails two stages: (i) locating people who are trapped and (ii) rescuing these people. Search and rescue operations are one of the top priorities after a disaster and thus fall mainly into the response stage of the disaster management cycle. Historically, search and rescue has often been carried out by international in-person teams. There are two main problems with this approach: first, international teams often arrive too late, and second, it is more cost-efficient to train local people. Time and cost are two critical resources during a disaster. The most successful search and rescue operations are carried out by relatives and immediate neighbours (Rom and Kelman, 2020).

Technology can help improve the efficiency, timeliness and cost effectiveness of locating and rescuing people. The location phase is critical: a well-functioning system should be able to accurately locate as many trapped people as possible, as quickly as possible, without compromising quality.

Key technologies

AI and GIS are used to process relevant data such as satellite imagery or social media posts to identify people in critical need. Communications networks are analysed and cross-referenced with situational reports to locate people. Search and rescue drones can be used to fly over affected areas. Drones are already widely used and are particularly helpful because of their ability to use thermal imaging to locate people in conditions such as darkness, thick vegetation, fog and smoke. Such systems can inform rescue teams in real time, reducing response times and increasing the number of people located.

A more experimental branch of technology is the use of autonomous search robots designed to locate and rescue people who have been trapped or injured. These could be used for a faster response in situations that are too risky for human intervention, such as nuclear catastrophes, fires, explosions or unstable infrastructure. However, search robots are still at the prototype stage. They are still not good at interacting and collaborating with humans and require extensive testing to ensure human safety (European Commission, 2019).

CASE STUDY

SARDO: Drones to locate victims

SARDO is a new prototype that helps locate sparsely distributed victims in remote or hard-to-reach areas. SARDO uses a combination of drone technology, ML and communication networks to take advantage of the relatively high penetration of mobile phones in today's societies. It seeks to solve the problem of cell phone outages during disasters due to the destruction of cell towers and disruption of networks. SARDO drones fly over the affected areas and act as cellular base stations, enabling the tracking and location of disaster victims' cell phones, making it easier and faster to locate people in need (Albanese, Sciancalepore and Costa-Perez, 2021).

1.2.5. Damage and loss assessment

Background

Damage, loss and needs assessments are critical components of disaster response and recovery. Needs assessments provide a general understanding of community requirements, while post-disaster needs assessments focus on specific, immediate needs arising from the disaster's impact, guiding emergency response and recovery efforts. Post-disaster needs assessments estimate the damage caused by the disaster and its impact on people, socioeconomic variables and physical assets. Specific damage and loss assessment methodologies were created by the UN in 1972 (Municipality of Beirut and UN-Habitat, 2020), but with the emergence of AI, these have entered a new era.

Understanding the damage and impact of a disaster is critical to formulating appropriate responses, allocating resources and planning for recovery and reconstruction. Getting reliable information in real time is key, especially in the aftermath of a disaster. During the first few hours of the response, it is essential to understand who is in critical need and which areas are most affected.

Key technologies

ML algorithms are often used to identify relevant data sources, such as by collecting images of damaged infrastructure from social media. Automated data pipelines can be used to geotag and locate unidentified images and continuously clean, standardize and update incoming data.

While ML is paving the way for rapid data processing and analysis, other technologies such as drones, GIS and remote sensing are also involved in the data-collection and monitoring steps. Drones can be used to access remote areas and obtain real-time footage, while GIS and remote sensing can provide detailed pictures of the situation.

CASE STUDY

2020 Beirut explosions

In the aftermath of the explosions at the Beirut docks in 2020, several agencies worked on rapid damage and loss assessment, including UN-Habitat, MapAction, UN Disaster Assessment and Coordination (UNDAC) and UK SarAid. Through remote observation and blast radius damage estimates, they analysed and mapped the impact on infrastructure and people and assessed socioeconomic vulnerability and areas in urgent need of assistance. This approach enabled them to evaluate the initial damage and assess losses rapidly, while providing detailed information on damaged buildings, internal structural damage and people in need (Municipality of Beirut and UN-Habitat, 2020).

1.2.6 Disaster relief logistic/resource allocation

Background

Disaster relief logistics and resource allocation are the processes of managing the acquisition, storage and distribution of resources as well as their intermediate and final transportation. Resources are usually physical goods and materials but may also be monetary. Timely and efficient resource allocation and logistic procedures are critical to the response and recovery phases.

During a disaster, resources are often scarce and even when they are available, getting them to the people who need them most is complicated. Relief logistics and allocation must address questions such as:

- Who is in most need of resources?
- What resources are needed?
- How will resources be delivered?
- How can resources be allocated most efficiently?
- How will resources be transported to their destination in a safe and timely manner?

Key technologies

Technology can provide the answers to many of these questions. 3D printing is being used to create unique components for machines, ensuring the functionality of critical systems during a disaster. Blockchain and communication networks are being used to manage cash transfers and other kinds of resource allocation, ensuring secure, fair and transparent distribution. The use of communication networks to distribute cash payments to phones or order supplies online proved particularly helpful during the Covid-19 pandemic (Stablein, 2020). Drones can be used to transport essential goods such as vaccinations or medical supplies to those in remote areas.

CASE STUDY

Field Ready

Field Ready was founded in 2014 with the goal of improving the way international aid is delivered. Field Ready has worked in Nepal, Syria, Iraq and the Pacific Islands, among other locations, providing unique 3D printing solutions to manufacture, repair and design components in challenging environments. Through training, the knowledge was transferred to local communities to further build resilience without dependency.

1.2.7 Emergency communication

Background

Emergency communications provide and deliver critical information to the public. There are many technologies designed to collect and gather actionable information, but the applications of these can fail if the information does not reach people in need. Informing people about disasters and the associated impacts, risks and recommendations are critical components of any disaster management cycle. However, the type and nature of communications can vary drastically depending on the disaster, the resources available and the number and characteristics of people affected. In some situations, it may be advisable to deliver information cautiously to avoid panic and escalation, but sometimes the opposite may be necessary when awareness needs to be raised (Panagiotopoulos et al., 2016).

Time, accuracy and outreach are key factors in the emergency communication process. The high penetration of social media among the population have led to platforms like Twitter and Facebook being used for emergency communication. This can help manage expectations about available resources while providing information on disaster relief activities. However, open communication channels make it difficult to assess the number of people reached, who they are and how they respond to the information (Subba, 2016).

Key technologies

Chatbots provide a more controlled approach to emergency communications. Powered by recent advances in AI, particularly NLP, chatbots can be a powerful tool for managing and communicating with the public during disasters. Typically, they use a combination of rule-based and ML-driven functionalities (Kosugi and Uchida, 2019). Chatbots can be used as intermediaries in emergency communication, for example, by processing medical requests and forwarding them to medical professionals (Ni et al., 2017). However, the language used by the affected community may constitute a limitation: English is well-established, but well-trained models may not be available for languages with fewer speakers.

These technologies depend on functioning communications networks. Emergency communications can also benefit from solutions that can adapt to the ever-changing conditions of a disaster situation and keep communications stable and operational. Integrating CPS into existing systems can help provide stable information and communications technology (ICT) services during disasters (Nishiyama, Suto and Kuribayashi, 2017).

CASE STUDY

Covid-19 chatbots: WHO health alerts

During the Covid-19 pandemic, WHO launched a chatbot on several services such as Facebook and WhatsApp that aimed to provide accurate information from a credible organization to reduce fear, uncertainty and misinformation (Sharma et al., 2017; WHO, 2020). Users could ask the chatbot about symptoms, statistics, current developments and response measures. Sharing high-quality information like this can lead to behavioural changes in the population (e.g., increased handwashing and social distancing), thus positively influencing the outcome of a pandemic or disease outbreak.

1.2.8 Situational awareness/actionable information gathering

Background

Situational awareness aims to provide the information needed to accurately assess a given situation or environment. It is an essential pillar of all disaster management cycles, supporting preparedness, response, recovery and resilience. The key dimensions of situational awareness are timeliness, coverage and relevance: an application designed to improve situational awareness should be able to process real-time information, ensure broad coverage of the event and provide actionable insights. These insights can be useful in all phases of disaster management.

Common tools for establishing situational awareness are dashboards and crisis maps which are used to display, visualize, aggregate and explain data that has been processed or transformed. Examples include the maps that tracked Covid-19 outbreaks . Data collection is thus critical for situational awareness. It must meet the requirements mentioned above:

- **Timeliness —** information should be provided in real time and update continuously.
- **Coverage —** it should include the whole scope of the disaster.
- **Relevance —** it should be directly relevant to the disaster event.

Key technologies

AI can be used to identify relevant events from social media, GIS, remote sensing and other related data sources. Crowdsourcing initiatives, mobile phones or drone footage are used to obtain on-the-ground information from hard-to-reach areas.

As the successful application of situational awareness supports real-time decision-making, the information collected needs to be processed and analysed quickly and accurately. Automated analysis pipelines that can quickly find, process and visualize relevant information are complex to build, but provide invaluable support for appropriate disaster response.

Such dashboards and situational awareness studies can monitor the evolution of a disaster management cycle, while keeping track of key variables that can mitigate subsequent disasters.

CASE STUDY

Actionable information gathering

Utilizing real-time mobile (big) data for emergency disaster response

In response to Türkiye's vulnerability to earthquakes, mobile operator Turkcell provides a real-time analytical tool called Galata to mitigate the impacts of earthquakes and help make informed decisions in real time. Galata processes over 100 billion events every day to quantify the number of people affected by a disaster across Türkiye (GSMA, 2020).

CASE STUDY

Situational awareness

KAP Covid — infodemic management

KAP Covid was created by the Johns Hopkins Center for Communication Programs in collaboration with WHO, Facebook, GOARN and MIT to address the problem of "infodemics" – an overabundance of information, including false information, that makes it hard for people to make informed decisions. This became prevalent during Covid-19, when the Internet provided limitless access to unverified information on the pandemic. The dashboard presented survey data from 1.5 million people in 67 countries, providing insights into attitudes and knowledge on Covid-19. This proved essential for policymakers and public health officials during the health crisis, helping to mitigate the impact of an infodemic.

1.3 CHALLENGES WITH IMPLEMENTATION

Challenges can arise from the implementation of technologies and their specific use cases. Each use case has its own issues and limitations. Below we aim to identify and summarize the key considerations:

- technical limitations
- data requirements
- data ownership and integrity
- practical considerations

1.3.1 Technical limitations

Technical limitations are often the reason why technologies cannot be successfully employed. These can be subdivided into a lack of technical knowledge, a lack of technical infrastructure which can prevent the use of a technology, and a lack of technical resources, which usually comes from financial constraints.

Technical knowledge and skills can range from simple activities such as operating drones to implementing highly complex systems such as blockchains, CPS or ML. There are typically two approaches to addressing a lack of technical skills. The quickest and easiest option is to hire a third party. However, this can be costly, less sustainable for long-term goals and does not improve local ownership of projects and disaster management. The second option is to train local or in-house staff. Although this option is more time-consuming, it is more sustainable in terms of long-term impact and benefits, as projects can be better tailored to people's needs, while creating employment opportunities for the community.

Time is often a constraint on creating technical infrastructure, as development is a trial-and-error process. Initial research is often conducted in isolated, controlled environments and is not transferred to the field, such that very few prototypes making it into production. A lack of technical infrastructure often hinders the successful deployment of applications in lesser developed countries and remote areas. Many applications require electricity, a stable Internet connection or access to mobile networks to work. The creation of a technology-enabling environment is therefore a critical prerequisite for the use of digital solutions in the disaster management cycle.

Once a technology or project has been developed for implementation, there may still be an information gap between disaster management researchers, policymakers and practitioners without proper coordination. While the developers of AI technologies will have technical knowledge, they may lack expertise in ethical application, which is where disaster management policymakers and practitioners can be helpful (Bora and Timis, 2021).

1.3.2 Data requirements

A key variable between the different use cases and technologies is data. Data is a critical enabler that determines the level of success. The key dimensions to consider in relation to data are access, quality, timeliness and relevance.

Data must first be identified and obtained, which can be challenging in humanitarian settings. Collecting real-time, up-to-date data while ensuring quality control requires a high level of automation, technical facilities and expertise as well as undamaged infrastructure. This translates into an overwhelming processing burden as the amount of data generated during a disaster cycle increases.

Secondly, data is valuable, so accessing and storing high-quality, relevant data properly often comes at a cost. This can be problematic for smaller companies and organizations with limited resources. Typically, highly specialized private companies collect and sell data, so partnering with the private sector could be beneficial.

Ensuring the quality of data is the next challenge when it is used for real-time decision-making. Quality comprises of completeness, accuracy, consistency, uniqueness and timeliness (Pipino, Lee and Wang, 2022). Data quality requirements should be determined and agreed on by both policymakers and technical experts. Data management should be continuously monitored so that potential gaps are discovered and eradicated early as to not poorly affect decision-making.

1.3.3 Data responsibility and integrity

Another important issue is the responsible use and collection of data, including privacy and integrity concerns, as these can have a direct impact on the lives of vulnerable groups. As a matter of principle, needs and prospects of said groups must be carefully assessed before data is collected and used. Practitioners need to identify potential risks and damage and identify and be aware of the legal and ethical frameworks that apply to their proposed use (Raymond et al., 2018).

The private sector must also adhere to these principles rigorously, particularly in public-private partnerships.

The following points provide a comprehensive framework for responsible data use in crisis management and address the complexities and challenges associated with data privacy, ethics and integrity:

- Informed consent and transparency: Responsible use of data includes obtaining informed consent from individuals whose data is collected. Transparency in how data is used, shared and protected is critical to building trust and maintaining ethical practices.

- Data minimization: Practitioners should take a data minimization approach, collecting only the information necessary to achieve specific crisis management objectives. This reduces the risk of data exposure and potential misuse.

- Anonymization and de-identification: Anonymizing or de-identifying data can help protect an individual's privacy while still allowing valuable insights to be gleaned from the information. This approach balances data utility with privacy preservation.

- Data security: Robust data security measures are essential to prevent unauthorized access, breaches and the potential exploitation of sensitive information. Encryption, access controls and secure storage protocols are critical components of this.

- Accountability and governance: Clear lines of accountability should be established to ensure that data use adheres to ethical and legal standards. Implementing appropriate governance frameworks helps maintain transparency and mitigate risk.

- Cultural sensitivity: Crisis management often involves diverse communities with unique cultural considerations. Practitioners must respect cultural norms and values when gathering and distributing information to avoid potential misinterpretation or miscommunication.

- Equity and inclusivity: Efforts to collect and share data should prioritize equity and inclusion. For crisis response to be effective, it is vital that information reaches all segments of the population, regardless of socioeconomic status or access to technology.

- Data sharing protocols: Collaboration among multiple stakeholders – including government agencies, NGOs and the private sector entities – requires well-defined data sharing protocols. These should address issues such as data ownership, the sharing frequency and mechanisms for secure data exchange.

- Capacity-building: Building the capacity of organizations and individuals involved in crisis management to handle data responsibly is essential. Training and education programmes can help practitioners understand the ethical, legal and technical aspects of data use.

- Continuous evaluation and improvement: The responsible use of data in crisis management is an ongoing process. Regular evaluation, feedback loops and continuous improvement efforts are essential if stakeholders are to adapt to evolving challenges and ensure ethical data practices.

- User empowerment: Individuals can gain control over their own data through mechanisms like data access requests, which allow them to review and modify their data as needed.

- International cooperation: Data privacy and ethical concerns transcend geographic boundaries. Collaborative efforts at the international level can establish harmonized standards and best practices for the responsible use of data in crisis management.

1.3.4 Practical considerations

Despite the many technological advances and opportunities promised by new technologies and research, it is important to consider the trade-off between high-tech and low-cost solutions. This depends on external factors such as the availability and accessibility of the technology, the resources available, the specific socioeconomic environment and the practicality of the application.

High-tech equipment can be damaged by natural disasters or stolen by individuals. If this occurs in remote areas, which is often more likely in disaster management, there is a greater risk that it will not be repaired or replaced. High-tech solutions also often come with higher inherent complexity, greater dependency on other technologies, and maintenance costs that may not outweigh the increase in performance over comparable low-tech solutions.

A good example of high-tech versus low-tech solutions can be seen in the use of AI (NLP) during the Covid-19 pandemic to automatically translate information that was otherwise only available in English into other languages used by vulnerable populations. This solution was fast, simple and did not require any new development. In this case, a simpler solution was more effective than experimenting with cutting-edge technologies.

CHAPTER 2

RISKS AND VULNERABLE GROUPS

02

Photo credit: UNDP Uzbekistan / Danielle Villasana

CHAPTER 2

RISKS AND VULNERABLE GROUPS

As the use of technology increases, it is important to be aware of the potential challenges and risks this use may bring.

2.1 DIGITAL DIVIDE

The OECD defines the digital divide as "…the gap between individuals, households, businesses and geographic areas at different socioeconomic levels concerning both their opportunities to access ICTs and to their use of the Internet for a wide variety of activities" (OECD, 2001). Digital technologies and access to the Internet helped many countries and individuals avoid total economic collapse during the Covid-19 pandemic. While more digitized countries and companies were able to accommodate remote work, people without access to these solutions often worked reduced hours, lost their jobs or could not use essential services.

In developing countries, the digital divide is much less pronounced, but there is often an overall divide between rural and urban areas. Sometimes there is no Internet coverage because the necessary infrastructure is not yet in place or access remains unaffordable for some of the population (ITU, 2019; ITU, n.d.). Other components of the digital divide include a lack of digital literacy and limited access to electricity and financial resources to bridge the gap. As developing countries experience more disasters, using digital solutions in disaster management can disproportionately affect those with fewer resources, further emphasizing the importance of bridging the digital divide through investment and training. This is especially true if scalability and accessibility are desired for equal application across the globe.

Another concern is biased decision-making. Data comes from sources (or users) with access to the platforms through which this data is collected. For example, social media data may overrepresent younger, English-speaking segments of a population with access to mobile data due to their urban location. Surveys may be disproportionately answered by male household members, introducing a gender bias. Basing decisions on incomplete data runs the risk of neglecting the needs of certain groups.

There are also risks relating to the protection and privacy of the data collected. Drones, IoT and crowdsourcing all collect data from individuals and communities who may not have given permission for their data to be collected or been informed of how their data will be used. While ensuring that any data collected is kept confidential is one solution to this problem, it is difficult to guarantee when these technologies are at risk of being hacked.

2.2 GOVERNMENT REGULATIONS

Governments may decide to restrict the technology that can be imported or used in the country, which can slow response times or impede access if an organization is denied a permit. This is typical of the use of drones. Alternatively, governments may heavily regulate the type of data that can be collected by the private sector, as is sometimes seen with remote sensing technology.

2.3 BIASED AI

As with all automated technologies, a programmer's bias can become part of the system. This bias is a particular concern for AI.[1] If an ML algorithm is taught through inherently biased examples, the machine will learn to replicate and internalize such biases in its decision-making. For example, an ML model trained to recognize "happy people" from images of Caucasian people smiling may associate "happy people" with both smiling and skin colour. The same is true for text, where the word "man" is more likely than the word "woman" to be associated with "boss" (Sharkey, 2019). While these AI failures are undesirable and must be overcome, the real consequences become deadly when evaluating examples such as automated weapons systems.

Another kind of bias in AI is spatial bias. A model trained on location-specific data may fail when applied to a different spatial environment (GFDRR, 2018). Similarly, there is bias over time as societal norms and values change, rendering an ML model discriminatory. This becomes problematic when (training) data preserves outdated norms, such as gender-biased language, but may also simply relate to information that has changed over time – the location of certain businesses or facilities, the name of a hospital or the laws of a country. AI models should be flexible

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[1] A well-curated reading list on biases in artificial intelligence is included in Malliaraki (2019).

enough to adapt to changes, which requires continuous model retraining. In a humanitarian setting, where lives are at stake, discrimination against vulnerable groups or incorrect results from ML models influencing DRM decisions can have dire consequences.

Another challenge is that it is not possible to explain or understand what drives a model's decisions. Without knowing, we cannot be sure that the rules the model has learned are just and fair or based on discriminatory factors. This lack of knowledge makes it difficult to evaluate and adjust models accordingly, contributing to mistrust and suspicion of new technologies and their capabilities (Diakopoulos, 2014).

Biased AI is caused either by design flaws, inadequate data, lack of expertise or the simple profit motive that hinders quality. Whether intentional or not, these flaws can potentially affect people's lives. It is thus good practice to have an internal or external expert for monitoring purposes such as background research and quality checks.

2.4 GENDER DIMENSION

Gender dynamics significantly influence ethical considerations in data collection and crisis management. Women's potentially limited access (or lack of access) to technology exacerbates these concerns, resulting in a gendered digital divide. This divide results from various factors, including socioeconomic disparities, cultural norms and unequal access to education and resources. As a result, women may be disproportionately underrepresented in digital spaces, depriving them of the benefits of technology-enabled information-sharing.

The implications of this digital divide are far-reaching. In crisis management scenarios, less connectivity among women means that the information circulating through technology platforms is predominantly representative of men's perspectives and experiences. This skewed representation can lead to a lack of gender-responsive information and resources, leaving women's specific needs, challenges and vulnerabilities unaddressed.

Furthermore, bias in data representation extends into the realm of AI. AI models are trained on existing data, and if that data primarily reflects male voices and viewpoints, AI algorithms may inadvertently perpetuate gender bias. For example, AI-driven decision-making processes may be skewed towards male perspectives, resulting in recommendations and actions that do not adequately address women's concerns and experiences.

Addressing the gender digital divide and its impact requires a multifaceted approach. This includes efforts to close the technology access gap and ensure that women have equal opportunities to benefit from digital platforms. It also includes actively seeking out and amplifying women's voices and experiences when sharing information during crises. In addition, data collection strategies must include gender-disaggregated data to ensure that AI models are trained on a more representative and inclusive data set.

Ultimately, recognizing the intersectionality of gender and technology in crisis management is essential to developing ethical and equitable data practices. By acknowledging and actively addressing these differences, practitioners can work towards a more inclusive and balanced approach to information-sharing that takes into account the diverse needs and perspectives of all individuals, regardless of gender.

2.5 ADDRESSING THE CHALLENGES

Addressing the challenges and gaps outlined above is possible. While it will take more than the efforts of the private sector to close the digital divide, such efforts can help prevent it from getting worse. For example, by working hand-in-hand with its Member Networks, CBi can begin implementing these technologies in disaster management for the benefit of some of the world's most vulnerable populations through a bottom-up approach. Doing so would prevent the digital divide from widening by giving power directly to these communities rather than relying on external funding and waiting for a trickle-down effect from richer countries.

Additionally, there are pre-emptive arrangements that allow for relevant data and technologies to be used in emergency situations to address the issue of strict government regulations on outside technologies.

Hiring a diverse team of trainers can help mitigate biased AI, as this ultimately originates in people's biases. By hiring people who are aware of existing biases, the data points used to train the ML can be controlled. This does not prevent bias altogether, so reprogramming may sometimes be necessary to control bias, which is possible because AI algorithms can be reviewed to find the problem and fix it.

CHAPTER 3

MAPPING TECHNOLOGIES TO PRIVATE SECTOR NETWORKS

03

CHAPTER 3

MAPPING TECHNOLOGIES TO PRIVATE SECTOR NETWORKS

Photo credit: Adobe Stock / Nathan

Harnessing technology for disaster management requires a multi-stakeholder approach. While the public sector can provide general guidance and funding, and academia can support this process through research and knowledge, the role of the private sector needs to be better understood.

First, we need to acknowledge that the private sector is the primary driver of the global digital revolution. Most innovations and solutions are developed by private companies, and with the growing trend of large multinational companies having their own research and development departments, the private sector is also disrupting academia and the way ideas are created and exploited. The greatest resource the private sector can offer is thus existing knowledge. A recent case study by the ITU showed that in two out of three cases of hardware solutions for disaster management, the private sector was the implementer while the government acted as a funding source (Minges, 2019). However, knowledge levels vary widely across regions and countries. Most solutions are still developed and maintained by companies based in developed countries, with only a fraction coming from developing and least developed countries. This and other problems relating to incentivizing and engaging the public sector are outlined below, followed by information on how to address them and what the private sector can contribute to disaster management.

3.1 THE ROLE OF THE PRIVATE SECTOR IN HARNESSING TECHNOLOGIES FOR DISASTER MANAGEMENT

In some ways, the private sector risks hindering efforts to adapt technology to disaster management cycles. A study by the Center for Global Development found that rich countries actively hinder the spread of technology across borders (Park and Käppeli, 2017). Disasters discriminate against less developed countries. Engaging multinational corporations in private sector networks can help bridge this gap. Waiving intellectual property rights may be another tool for achieving this, albeit a more controversial one.

The private sector must be encouraged to promote and support technology-based disaster management. In particular, business depends on a healthy and reliable socioeconomic environment that supports the business-as-usual framework that disasters threaten. However, the private sector has indirect positive effects through partnerships to adopt technologies for preparedness, response, recovery and resilience. In this way, employees' skills increase, as does the company's overall competitiveness and market value, along with its potential to advance in other fields. This is particularly the case for micro, small and medium-sized enterprises (MSMEs), which can more easily absorb new technologies.

When adopting digital solutions, technological readiness must not be overlooked. There are several dimensions to readiness: the adopting entity should have the knowledge and skills to maintain the technology and understand its mechanisms, limitations and implications. Adopting new technologies also involves a financial commitment. Staff need to be trained on an ongoing basis, and investments in hardware and software are required, highlighting the importance of adequate funding and the development of long-term partnerships between the public sector, private sector and academia.

In addition, private sector challenges related to digital maturity, long-term plans and available resources require a thorough assessment. Although methodologies to assess the digital maturity of public sector disaster management exist, the private sector lacks guidance and models. The development of standardized frameworks would be a helpful foundation for the successful and sustainable digitization of private sector networks and disaster management practices. Therefore, it is necessary to understand what environments enable and incentivize private sector networks to contribute to digital solutions for disaster management – for example, financial security through funding opportunities from governments and public agencies to continue projects.

Private sector involvement has the power to increase local ownership of digital solutions for disaster management. Harnessing local knowledge can reduce the digital divide between countries while improving local preparedness and crisis response. The private sector also has the potential to reach a wider audience than governments to showcase and teach best practices in disaster management, especially since some people trust businesses more than the government (Dill and Wilberding, 2021). In addition to knowledge, technical expertise and data, the private sector has access to infrastructure and partnerships that can be critical. A good example is access to telecommunications channels that support disaster preparedness, response, recovery and resilience.

3.2 MAPPING

CBi can reach 789,000 local businesses through its local Member Networks. CBi Member Networks represent both large corporations and MSMEs. After working on disaster preparedness and resilience, these networks have responded to 132 crises, reached 23 million people and raised US$84 million. These statistics are evidence of an active network that is ready and able to benefit from appropriate technological integration for their individual countries and common disasters. The purpose of this section is to provide an overview of common problems, describe how they can be overcome and make practical recommendations. This chapter will first outline our workflow for mapping technologies to the CBi private sector networks and conclude with some general recommendations from the authors and the CBi Network Coordinator and guidelines.

3.2.1 Network assessments

Mapping technologies and their prospective use cases to existing private sector networks requires a multi-step approach. It is necessary to understand country and regional differences, look at specific, prevalent disasters, and attain a good overview of the different levels of readiness and pre-existing resources/knowledge at the private sector members' disposal. Most importantly, it is necessary to be practical and focus on people's needs and immediate assistance. Therefore, the first step in implementing the most appropriate technologies is to assess the digital maturity, readiness, available resources and partnerships of the implementing or adopting party. Below is an example of a list of typical questions for the initial assessment:

- What is the population's level of access to the Internet and electricity?
- How many people have mobile phones and how actively are they used?
- Has disaster-related data already been collected and is it currently available?
- Is there historical data?
- Is there an existing data-collection mechanism for during and after disasters?
- How is the data stored?
- Is the data tagged with socioeconomic indicators and geolocated? If not, what is missing?
- What is the level of technical knowledge of the implementation or adaptation entity?
- Are there existing partnerships between academic establishments, the private sector and the public sector that can be leveraged?
- Are there existing digital solutions and working practices that can be improved before a new approach is adopted?

Risks are typically natural hazards (e.g., tropical storms and earthquakes), but epidemics/pandemics are also a common risk. The following list contains additional questions that provide an understanding of the most significant risks and disasters for each network and country:

- What are the most prevalent disasters?

- What are the main problems caused by these disasters, and which are the most challenging for the specific networks and countries to address?
- Which (vulnerable) groups are affected by the disasters and exposed to the associated risks?
- Which cycle in the disaster management process is most in need of support?

The information available will vary considerably from network to network, country to country and region to region. Therefore, in some cases, only reasonable estimates can be made. Below is an example of a network assessment using standardized rankings from two reports: the Global Digital Readiness Index (Cisco Public, 2020) and the UNCTAD Country Digital Readiness Ranking (UNCTAD, 2021). The Global Digital Readiness Index is used to assess the digital maturity of each network, represented by technology infrastructure (TI) and technology adoption (TA). The UNCTAD rankings go from high to upper middle, lower middle and low based on ICT deployment, readiness and development activities, industry activity and access to finance.

Example Network Assessment: The Philippines

Relevant hazards: Typhoons, earthquake, volcanic eruption, floods

Digital maturity: High: The Philippines IT sector has demonstrated a strong capacity to develop and adopt digital solutions. The Philippine Disaster Resilience Foundation (PDRF), a CBi Member Network, is one of the most technologically advanced: the PDRF has established the GIS-based HANDA platform for disaster management information. TA: 0.74, TI: 1.02, UNCTAD: upper middle.

Relevant technologies: AI/Machine Learning, GIS, Crowdsourcing, IoT, Blockchain

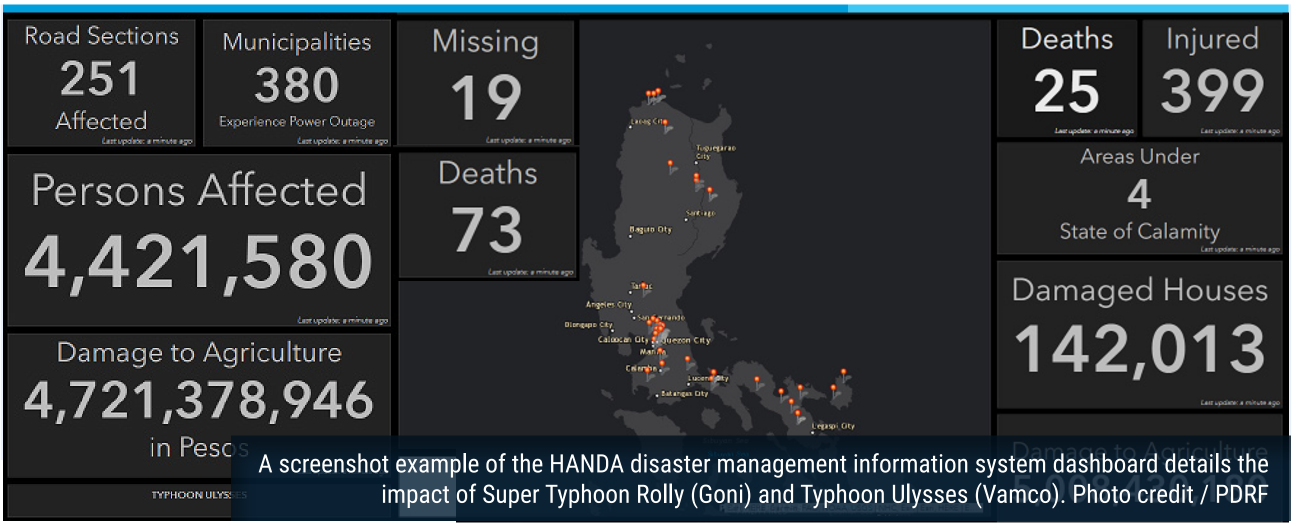
CASE STUDY

HANDA – The Disaster Information Management (DIM) System

The Philippine Disaster Resilience Foundation (PDRF) is the coordinator of private sector efforts in disaster risk reduction and management in the Philippines and is a CBi Member Network.

During disaster response, the PDRF Emergency Operations Center coordinates the efforts of member companies and ensures that the needs of vulnerable populations are addressed. PDRF-HANDA serves as a unified platform that eliminates the waiting time and provides focused efforts that enable member companies to assess and reduce their risk prior to potential disasters. The platform also allows these companies to plan relief and rehabilitation efforts that complement business continuity plans and programs. This system integrates all reliable, accurate, and timely information on disaster management. The DIM System employs the customized ArcGIS Online platform from ESRI called HANDA or Hazard and Disaster Analysis for Business Resilience.

For more information, please visit: https://www.pdrf.org/emergency-operations-center/functions/


Road Sections 251 Affected
Municipalities 380 Experience Power Outage
Missing 19
Persons Affected 4,421,580
Deaths 73
Damage to Agriculture 4,721,378,946 in Pesos
Deaths 25
Injured 399
Areas Under 4 State of Calamity
Damaged Houses 142,013

A screenshot example of the HANDA disaster management information system dashboard details the impact of Super Typhoon Rolly (Goni) and Typhoon Ulysses (Vamco). Photo credit / PDRF

Example Network Assessment: Mexico

Relevant hazards: Earthquake, Wildfire, Flood, Landslide, Hurricanes

Digital maturity: Medium: Mexico is experiencing rapid growth in mobile and Internet connectivity across the whole country, with access expected to reach 94 per cent of Mexicans by 2024 (OECD, n.d.). In 2018, the country gained access to an IT platform set up by a private trust to track the progress and real impact of reconstruction programmes on beneficiaries. TA: 1.01, TI: 0.99, UNCTAD: upper middle.

Relevant technologies: AI/Machine Learning, Cloud storage, crowdsourcing

CASE STUDY

Mexican businesses launch collaborative platform to improve disaster risk reduction

A coalition of Mexican businesses has launched a virtual platform to foster collaboration between the private sector, the Government, the United Nations and humanitarian partners during emergencies. The new platform, Unidos por Ellxs, will support private sector engagement in disaster risk reduction in Mexico. The project, supported by CBi, is being implemented by the CBi Member Network in Mexico, the National Center for Epidemiological Emergencies and Disasters (Centro Nacional de Apoyo para Contingencias Epidemiologicas y Desastres, CENACED), in partnership with national authorities, the United Nations Office for the Coordination of Humanitarian Affairs (OCHA) Regional Office for Latin America and the Caribbean, the United Nations Development Programme (UNDP), the United Nations Office for Disaster Risk Reduction (UNDRR) and humanitarian partners.

For more information, please visit: https://www.connectingbusiness.org/news-events/news/mexican-businesses-launch-collaborative-platform-improve-disaster-risk-reduction.

Example Network Assessment: Vanuatu

Relevant hazards: Volcanic eruption, cyclones

Digital maturity: Medium:

The use of the Internet and technologies is not widespread in Vanuatu, but the network has been exposed to the use of technologies in its work through partnerships. In response to Covid-19 and Tropical Cyclone Harold, the network has implemented a blockchain-based cash transfer programme. Vanuatu was not included in either of the network assessment

Relevant technologies: AI/Machine Learning, Remote Sensing, Drones, GIS

CASE STUDY

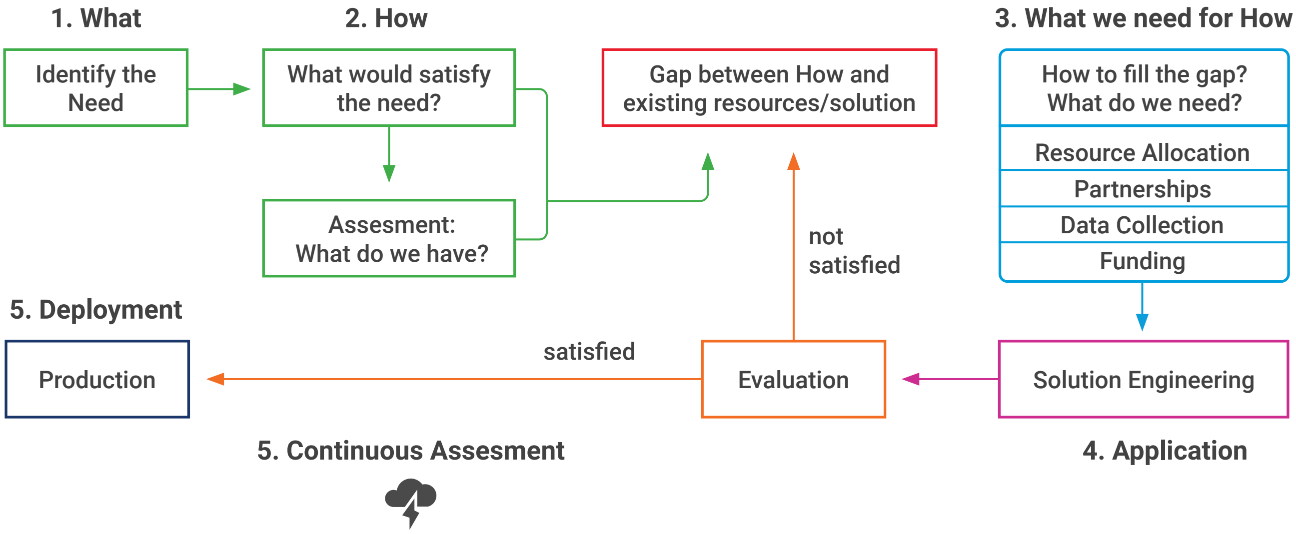
Case study: The unblocked cash experience in Vanuatu

VBRC is a CBi Member Network that works with businesses in Vanuatu on disaster preparedness, response and recovery. In 2020–2021, VBRC supported businesses in the OXFAM UnBlocked Cash humanitarian programme in Vanuatu.

One of the key benefits of the approach taken in this programme is that by engaging commercial businesses in the response, VBRC has simultaneously supported the recovery of communities and small businesses within them, strengthened value chains and provided more sustainable long-term solutions. Ultimately, this builds resilience across the broader economy and community (Barnes, 2021).

Mele Rara is an unblocked cash vendor in the rural village of Tasiriki where he runs a fish market. He has new customers and has made increased profits which have helped him and his family in the wake of cyclone Harold. Photo credit: Arlene Bax / Oxfam in Vanuatu.

3.2.2 Recommendations



Based on the discussions so far, recommendations have been made for the networks that address the assessment of digital maturity and capacity-building, the use of digital technologies for the management of the most common natural hazards and specific action points depending on the current digital maturity and readiness of the networks.

First, each network should complete a standardized Digital Network Assessment, a draft of which is provided above. This assessment provides an in-depth understanding and comparison of each network's digital maturity and readiness. This will help to determine which technologies are more appropriate for implementation, depending on the context. Regular capacity-building activities, such as training sessions, help raise awareness and strengthen the understanding of the use of technologies in disasters. In addition to technology-specific training sessions, capacity-building activities on humanitarian data collection and analysis standards are highly recommended. Additional activities such as data clinics and consultations with technical specialists would help CBi Member Networks address their current needs and develop their own digital solutions. In addition, long-term public-private partnerships can help networks prepare for, develop and implement digital solutions. Finally, having these systems in place before disasters strike should be a priority. Dedicated technical groups should develop solutions for such scenarios in advance, including the recommendations already mentioned, such as hosting webinars or training sessions.

In some cases, it may be advantageous to build on existing technologies rather than start from scratch. In other cases with limited exposure to technologies, cloud computing and GIS can be easily applied to networks. The combination of crowdsourcing and cloud computing addresses the lack of availability of data to support immediate disaster response and post-disaster recovery. Similarly, GIS technologies provide general support to all disaster management by effectively analysing and visualizing geospatial data.

The most common natural hazards among CBi Member Networks are floods, wildfires, droughts, landslides, earthquakes and cyclones. Summarizing previous discussions, the following recommendations apply to the use of technologies for each of these hazards.

Given the importance of geographic and socioeconomic contexts for flood prediction, thoroughly adapting predictive models through partnerships and prototype solutions is recommended to avoid replication. Although more time-consuming, prototype implementation is beneficial as it demonstrates the possibilities and limitations and increases local data and technology literacy and knowledge, creating a much more sustainable approach. Activities such as situational awareness training can improve flood response through data dashboards and coordinated activities. While wildfires and landslides are difficult to predict, damage and loss assessments and situational awareness can aid in disaster response and recovery. Before disasters strike, technologies such as IoT, drones, remote sensing, GIS and AI can benefit existing early warning systems.

For droughts, technologies such as IoT and GIS can support early warning systems and improve its accuracy. Collecting rainfall and temperature data from multiple sources and digitally processing it increases accuracy. If the country has good communication network coverage, distributing alerts via SMS or social media is highly recommended to reach more people.

Earthquakes can cause intense infrastructure damage and do not discriminate against infrastructure that is critical to disaster response. Technologies such as 3D printing can be used to replace essential delivery and transportation parts. Similarly, technologies such as drones can be used to provide immediate relief when infrastructure is too damaged to deliver aid by other means. Blockchain and cloud computing can also facilitate the effective and secure storage/transmission of information in the event of major infrastructure damage.

AI and ML can be used to predict cyclones. AI-powered solutions calculate a cyclone's path and predict the potential losses based on the population data, helping to minimize the impact of the hazard. Crowdsourcing is also proving useful in cyclone response, as it can quickly gather information from multiple sources to depict the level of response required.

For networks with limited exposure to digital technologies and low levels of digital maturity, GIS and AI/ML are recommended, because these technologies do not require consistent Internet connectivity or widespread, immediate access to the population. Cloud computing may also be a viable option for data storage and analytics, as it does not require hardware and can be used with limited Internet access. Overall, it would be advisable for low-digital-maturity networks to strengthen their technical capacities and explore the options outlined above to move forward.

As most medium-digital-maturity networks are located in countries with significant Internet and mobile phone coverage, there is room for experimentation. However, the first step is to deepen expertise in existing technologies and strengthen data collection practices. From this foundation, it will be possible to build expertise in technologies such as blockchain, chatbots and NLP to accelerate data collection from social media users.

Countries with a high level of digital maturity are in a better position to focus on more advanced technologies and practices. This does not mean that networks should stop using crowdsourcing and automation to further develop their capacity and data collection. Instead, networks should begin to customize technologies and solutions specific to their needs and socioeconomic contexts. In the future, there may be opportunities for networks with a high level of digital maturity to support their partners by sharing expertise, thereby increasing local ownership of disaster management processes and technologies together.

3.2.2.1 Prototype and ongoing projects

In 2020, CBi and UNDP's IICPSD SDG AI Lab partnered to conduct a landscape analysis and map frontier technologies for use in disaster risk management. The SDG AI Lab prototyped two digital solutions for disaster risk management using NLP and GIS technologies. The NLP prototype aimed to support the CBi Secretariat's work by analysing the private sector's engagement in disaster contexts. The project created a scalable data pipeline to collect and analyse over 50,000 corporate social responsibility reports to identify corporate activities related to disaster management. The project and its decision-support tool can help the CBi Secretariat and its networks to map the wide range of activities in the disaster management cycle and highlight new opportunities that would otherwise go unseen.

On the other hand, the GIS prototype provided support to the Philippines Member Network by aggregating information on the exposure of medium-sized enterprises to natural hazards. The Philippines Member Network worked with the SDG AI Lab to develop an online tool, the Private Sector Risk Exposure Map. This was inspired by members' good practices, like HazardHunter, developed by the Philippine Institute of Volcanology and Seismology (PHIVOLCS). HazardHunter is both an online dashboard and a map; it contains natural hazard data layers for the whole country from various sources and exposure maps such as schools or health centres.

CHAPTER 4

CONCLUSION AND OUTLOOK

04

CONCLUSION AND OUTLOOK

The aim of this report was to present key technologies for disaster management, illustrate how they are most commonly used and outline the main challenges and key considerations associated with them. Particular emphasis has been placed on the potential involvement of the private sector, to provide a better understanding of what is needed to engage the private sector in technology-driven disaster management and how technologies can be useful and promising.

The key takeaway from this report is that modern disaster management requires modern technologies and that its impact is enhanced when combined with these. Since the introduction of these technologies in disaster management, their use, impact and importance for preparedness, response, recovery and resilience has increased, with promising results. However, as technology becomes more mainstream in disaster management, the digital divide must be addressed simultaneously. The main challenges to bridging the digital divide are limited/difficult access to quality data and a lack of technical expertise among practitioners. Yet technology in disaster management can save lives and livelihoods. Given the right incentives, the private sector has an important role to play in bridging the technology gap and participating in technology-enabled disaster management. This brings its own challenges for the private sector, as engaging in technological disaster management in networks with low digital maturity and low willingness to integrate technologies into their practice can be a barrier. However, it was concluded that there are technologies that are applicable to all networks, such as AI/ML.

Based on observations from the field and CBi Member Networks, the following recommendations were made to advance technology-driven private sector disaster preparedness, response, recovery and resilience. The first is to develop a standardized digital maturity assessment framework for the private sector in each context to ensure that the digital maturity and readiness of the private sector and its networks are assessed as accurately as possible. Secondly, the resources needed for a digital response must be made available and accessible, possibly through funding opportunities and partnerships between the public, private and academic sectors. It will then be important to address and improve the technical knowledge, skills and digital literacy of the personnel involved through training and involvement in prototype projects to gain hands-on experience. For all this to happen, the private sector needs to be incentivized and motivated to adopt new technologies in their working practices. This can be done by providing training on the importance of these technologies and addressing financial risk by encouraging partnerships on this front.

Overall, it is strongly recommended to encourage the development of technological solutions for disaster management, whether through training, webinars or consultations. For best results, the recommendation is to provide practical examples to private sector networks and other practitioners in the field. The aim is to integrate relevant projects involving work with data and technology into the current working practices of networks, private sector members and the CBi. Further research and incentivization can help community-based private sector networks support their communities effectively when disasters strike, helping people globally.

CHAPTER 5

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05

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