Emerging technologies in the humanitarian sector

Methodology report

Pauline Paille, James Besse, Hampton Toole, Chryssa Politi, Shruti Viswanathan, Eunice Namirembe, Jyoti Nayak, Sergi Martorell, Iain McLaren, Christopher Tyson, Charlie Wilkening and Jacob Ohrvik-Stott

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Preface

This report was produced as part of a project commissioned by the UK Humanitarian Innovation Hub (UKHIH) that explored the adoption and use of emerging technologies in the humanitarian sector and associated barriers and challenges. This document presents the detailed project methodology.

The underpinning research activities across the three phases of the project were conducted between November 2023 and April 2024. This project also explored specific technology areas with strong potential within the humanitarian sector; developed guidance to help humanitarians seeking to adopt these technologies; and investigated opportunities for foresight initiatives embedding emerging technologies.

This report should be read in conjunction with the other outputs of this study: the *Deep Dive Series,*[1] *Technology Foresight Concepts*[2] *and Technology Guidance*[3] documents. In addition, the study developed two case studies on Cash and Voucher Assistance (CVA) and biometrics.[4]

The study was conducted by RAND Europe in partnership with Athena Infonomics and glass.ai.

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2 Paillé, Pauline, James Besse, Hampton Toole, Chryssa Politi, Shruti Viswanathan, Eunice Namirembe, Jyoti Nayak & Jacob Ohrvik-Stott. 2024. *Opportunities for supporting humanitarians: Technology Foresight Concepts*. Santa Monica, Calif.: RAND Corporation. RR-A3192-4. As of 17 October 2024: www.rand.org/t/RRA3192-4

3 Paillé, Pauline, James Besse, Hampton Toole, Chryssa Politi, Shruti Viswanathan, Eunice Namirembe, Jyoti Nayak & Jacob Ohrvik-Stott. 2024. *Opportunities for Supporting Humanitarians: Technology Guidance*. Santa Monica, Calif.: RAND Corporation. RR-A3192-3. As of 17 October 2024: www.rand.org/t/RRA3192-3

4 Toole, Hampton, Pauline Paillé, Chryssa Politi & Jacob Ohrvik-Stott. 2024. *Humanitarian Technology Adoption Case Study: Technology-enabled Cash and Voucher Assistance.* Santa Monica, Calif.: RAND Corporation. RR-A3192-5. As of 17 October 2024: www.rand.org/t/RRA3192-5;
Paillé, Pauline, Hampton Toole, Chryssa Politi & Jacob Ohrvik-Stott. 2024. *Humanitarian Adoption Case Study: Biometrics*. Santa Monica, Calif.: RAND Corporation. RR-A3192-6. As of 17 October 2024: www.rand.org/t/RRA3192-6

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Abbreviations

AI	Artificial Intelligence
CFFS	RAND Europe Centre for Futures and Foresight Studies
GSMA	Global System for Mobile Communications Association
IDP	Internally Displaced Persons
LMIC	Low- and Middle-Income Country
ML	Machine Learning
NGO	Non-Governmental Organisation
OCHA	Office for the Coordination of Humanitarian Affairs
RAG	Red-Amber-Green
TRL	Technology Readiness Level
UKHIH	United Kingdom Humanitarian Innovation Hub
UN	United Nations
WASH	Water, Sanitisation and Hygiene
WFP	World Food Programme

Chapter 1. **Introduction**

In November 2023, RAND Europe, in partnership with Athena Infonomics and glass.ai, launched the *Emerging Technologies for the Humanitarian Sector* project. This initiative, funded by the UK Humanitarian Innovation Hub (UKHIH), is the first stage of the Hub's wider programme of work exploring opportunities to support humanitarian-sector organisations to effectively consider how, or whether, to adopt technologies in their work.

The United Nations (UN) Organisation for the Coordination of Humanitarian Affairs' (OCHA) 2023–2026 Strategic Plan notes that the humanitarian sector is facing an exponential rise in humanitarian needs while simultaneously 'buckling under its resource constraints'.[5] Technologies offer a vital means of potentially bridging this growing needs–resources gap,[6] but OCHA cautions that these systems should be people-centred, durable and promote concrete outcomes. Acknowledging this context, this project included three overarching aims:

1. Understand and define trends in the adoption and use of emerging technologies within the humanitarian sector.[7]
2. Identify key emerging technologies that could strengthen humanitarian practice through an online survey.
3. Envisage a future research and innovation journey for the identified key emerging technologies.

To fulfil these objectives, the study team adopted a mixed-methods approach that included a literature review, semi-structured interviews, surveys and questionnaires, workshops, horizon scanning and web reading. Figure 1.1 below provides a project timeline that outlines the three research phases and the underpinning research activities conducted in each.

This document provides a detailed description of the project's methodology and research activities. It supplements the *Deep Dive*

5 Office for the Coordination of Humanitarian Affairs (OCHA). 2023. OCHA's *Strategic Plan 2023-2026: Transforming Humanitarian Coordination*. As of 6 August 2024: https://www.unocha.org/publications/report/world/ochas-strategic-plan-2023-2026-transforming-humanitarian-coordination

6 The UK Foreign, Commonwealth & Development Office (FCDO) also encourages 'putting science, technology and data at the heart of our actions' as a 'key pillar' of the Humanitarian Framework. See: Foreign Commonwealth and Development Office (FCDO). 2022. 'Policy paper: UK humanitarian framework.' FCDO Humanitarian and Migration Directorate. As of 6 August 2024: https://www.gov.uk/government/publications/uk-humanitarian-framework/uk-humanitarian-framework

7 UKHIH commissioned a distinct project to explore the adoption and use of artificial intelligence (AI) and machine learning (ML) in the humanitarian sector. These technologies were not within the scope of the project presented in this document.

Figure 1.1 Overview of research activities

Source: Study team analysis.

Series,[8] *Technology Foresight Concepts*[9] and *Technology Guidance*[10] documents developed as part of this study.

1.1. Structure of the document

The remainder of this report is structured as follows:

- **Chapter 2 – Phase 1 activities** provides an overview of the activities conducted in the first phase of the study, including the primary desk research and horizon scanning, scoping semi-structured interviews and web-reading activities.
- **Chapter 3 – Phase 2 activities** presents the activities conducted by the study team, building on the Phase 1 activities, that led to the development of the technology deep dives.
- **Chapter 4 – Phase 3 activities** outlines the proposed opportunities to further support humanitarian stakeholders in their adoption and use of emerging technologies. This section outlines the activities conducted by the study team to develop technology guidance and a foresight initiative with the objective to support the responsible adoption of emerging technologies and ensure wide-ranging participation from affected communities.

8 Paillé, Pauline, James Besse, Hampton Toole, Chryssa Politi, Shruti Viswanathan, Eunice Namirembe, Jyoti Nayak, Sergi Martorell, Iain McLaren, Christopher Tyson, Charlie Wilkening & Jacob Ohrvik-Stott. 2024. *Emerging technologies in the humanitarian sector: Technology Deep Dive Series*. Santa Monica, Calif.: RAND Corporation. RR-A3192-1. As of 17 October 2024: www.rand.org/t/RRA3192-1

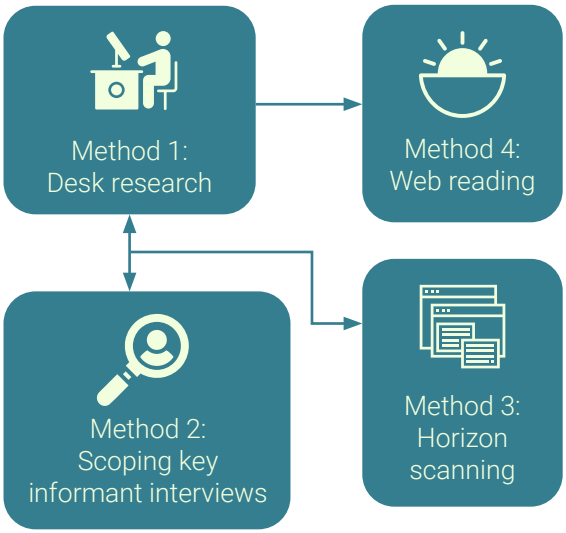
9 Paillé, Pauline, James Besse, Hampton Toole, Chryssa Politi, Shruti Viswanathan, Eunice Namirembe, Jyoti Nayak & Jacob Ohrvik-Stott. 2024. *Opportunities for supporting humanitarians: Technology Foresight Concepts*. Santa Monica, Calif.: RAND Corporation. RR-A3192-4. As of 17 October 2024: www.rand.org/t/RRA3192-4

10 Paillé, Pauline, James Besse, Hampton Toole, Chryssa Politi, Shruti Viswanathan, Eunice Namirembe, Jyoti Nayak & Jacob Ohrvik-Stott. 2024. *Opportunities for Supporting Humanitarians: Technology Guidance*. Santa Monica, Calif.: RAND Corporation. RR-A3192-3. As of 17 October 2024: www.rand.org/t/RRA3192-3

Chapter 2. **Phase 1 activities**

To gain a better understanding of the humanitarian sector and its inherent challenges, and to identify relevant emerging technologies, the study team conducted the activities presented in Figure 2.1 in the first phase of the research.

Figure 2.1 Overview of Phase 1 research activities



Source: Study team analysis.

2.1. Mapping emerging technology use in the humanitarian sector

2.1.1. Scoping key informant interviews

The study team conducted six participant-led, semi-structured scoping interviews between December 2023 and January 2024, with researchers and practitioners working in the humanitarian sector. The interviews sought to understand the challenges humanitarian organisations are facing and how emerging technologies have been, or could be, used to address them. The interviews also helped to map the humanitarian sector.

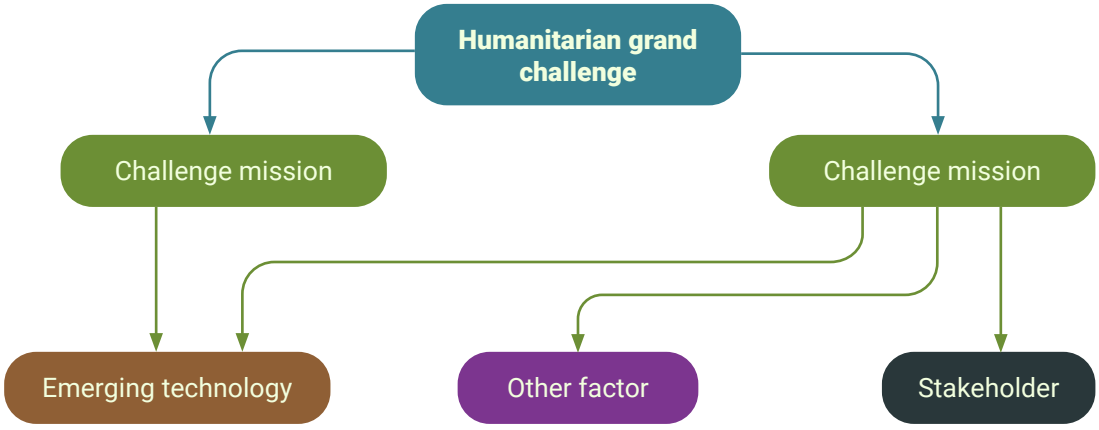
The scoping interviews were structured around an innovation-oriented framework comprised of 'grand challenges' and corresponding 'missions', which are aimed at producing clear outcomes to address the overarching challenge identified. Within each mission, underpinning activities include engagement with a variety of stakeholders as well as identification of enablers and barriers.[11]

Interviewees were first asked to define one to two 'humanitarian grand challenges' out to 2030 (i.e. high-level challenges pertaining to core humanitarian activities) that would be used as the basis for identifying underpinning activities, namely individual 'missions' that could be undertaken over the next decade to help address these challenges.[12] With these boundaries set, participants were then asked to identify and discuss specific organisations, issues and technologies that could be relevant to these missions, and the relationships between them. Figure 2.2 provides a visual representation of this framework.

11 Mazzucato, Mariana. 2018. 'Mission-oriented innovation policies: challenges and opportunities.' *Industrial and Corporate Change* 27(5): 803–815. As of 6 August 2024: https://doi.org/10.1093/icc/dty034

12 Mazzucato, Mariana & George Dibb. 2019. 'Missions: A beginner's guide.' UCL Institute for Innovation and Public Purpose, *Policy Brief* series (IIPP PB 09). As of 6 August 2024: https://www.ucl.ac.uk/bartlett/public-purpose/sites/public-purpose/files/iipp_policy_brief_09_missions_a_beginners_guide.pdf

Figure 2.2 Scoping interview framework



Source: Adapted from Mazzucato (2018).

Interviews were conducted using Microsoft Teams and were between 45 minutes and 1 hour in length. The interviews were led by a member of the study team, supported by one to two note-takers and recorded based on the interviewee's preference. To facilitate both discussion and note-taking, the study team used the online visualisation software Kumu. During the interview, the interviewer created a map of concepts, capturing the discussion in a form that the interviewee could immediately contribute to and engage with.

Interview notes were reviewed by the study team and analysed through a thematic analysis to triangulate the longlist of challenges and emerging technologies identified through horizon-scanning activities (see Section 2.1.2 and Annex A).

Table 2.1 provides an overview of the individuals interviewed, with their affiliation based on their attribution preference.

The interview protocol for the scoping interviews is presented in Box 1.1.

Table 2.1 Overview of scoping key informant interviewees

Date	Name	Affiliation
12/12/23	Daniela Weber & Stephanie Siy	NetHope
19/12/23	Anonymous	-
05/01/24	Anonymous	Ontonomic
05/01/24	Christian Cirhigiri	Search for Common Ground
12/01/24	Anonymous	Compassion International
18/01/24	Anonymous	GSMA
25/01/24	Anonymous	Oxfam

Box 1.1 Scoping interview protocol

Part 1 – Introduction

Q1. Could you please tell us a little bit about yourself, your background(s) and relevant experience regarding the humanitarian sector and the use of emerging technologies?

Part 2 – Humanitarian grand challenge

Q2. What is one [or more] major current or future challenge(s) (up to 2030) in the humanitarian sector that you think we should explore through this project?

- Which of the UN humanitarian clusters does this relate to? (diagram below as reminder)
- What stages of humanitarian action does the challenge relate to? (diagram below as reminder)
- Do you think this challenge is likely to change in its scale or form over the next ten years? If so, how?
- How does this challenge vary across regions globally?

Part 3 – Missions

Q3. Within your grand challenge area, what are some specific issues you or the wider sector are working to solve?

Q4. Within your grand challenge area, what are some specific opportunities you or the wider sector are working on to realise?

- Do you think these issues and opportunities are likely to change in their scale or form over the next ten years? If so, how?
- How do these issues and opportunities vary across regions globally?
- What would 'success' in ten years' time look like for these issues and opportunities?

Part 4 – Emerging technologies

Q5. What novel technologies available today are relevant to the missions you just described?

Q6. What technologies that could develop in five to ten years' time could be relevant?

- What applications, systems or infrastructure could be needed for these technologies to function?
- What technologies support or are interoperable with the technologies you've mentioned?
- What regional variations are there in access to these technologies?

Part 5 – Stakeholders

Q7. Which stakeholders are most influential to the missions and technologies we've discussed?

- Who builds the technologies you've mentioned?
- Which NGO and civil society groups are active in this space?
- Which policymakers and governmental agencies are active in this space?

Part 6 – Other related factors

Q8. Is there anything else relating to these missions, technologies and stakeholders you think is helpful for us to be aware of?

- How might this system change over the next ten years?
- Are there any ethical issues associated with these technologies or missions?
- Are there any other practical challenges associated with these missions or technologies?
- Are there any helpful pieces of relevant research or guidance we should read?

Part 7 – Interview close

Q9. Further to the various elements that you mentioned during the interview, is there anything else that you would like to add?

Q10. Do you have any further comment or observation that you would like to make?

If there are any relevant documents that you think might be helpful in the context of our project, please do share them with us.

Thank you for your time.

2.1.2. Horizon scanning

Horizon scanning is a methodology that involves systematically searching for early signals of change that could potentially impact a sector or wider society in the future. This includes technological advancements that may not yet be widely recognised. These signals – individual pieces of evidence of a potential development, such as a patent application, discovery research article or technology pilot application – are subsequently analysed to identify thematic patterns of similar signals that may collectively represent emerging trends.[13]

The study team used horizon scanning to identify emerging technologies that could be used within the humanitarian sector, the contexts in which they are deployed or considered, and the challenges associated with their adoption and use. Following a structured process established within RAND Europe, the first step defined the search strings and relevant data sources for the desk research. These strings combined context-specific terms grounded in the UN humanitarian clusters (e.g. 'food security', 'health' or 'humanitarian response') with established futures and foresight terms intended to elicit emerging technologies (e.g. 'future scenarios', 'future of', 'trends' and 'emerging technologies'). Snowball searching – looking for other papers cited in the core papers reviewed – was used to identify additional articles to supplement the initial searches and results. Further recommendations were also made by RAND Europe and UKHIH based on previous experience. The technology applications identified through web-reading activities (see Section 2.2) were triangulated with the horizon-scanning results. The study assessed technologies against their technology readiness level (TRL) or level of maturity and only selected technologies up to pilot stage level.[14]

Data sources explored included databases and academic journals (e.g, Google Scholar, the *Journal of Humanitarian Affairs and the Journal of Futures Studies),* patent databases, such as Espacenet and Patsnap,[15] and websites for humanitarian innovation hubs, accelerators and funds, including the World Food Programme Innovation Accelerator,[16] ReliefWeb,[17] the Global System for Mobile Communications Association (GSMA) Innovation Fund for Anticipatory Humanitarian Action[18] and

13 Grand-Clement, Sarah. 2019. 'How Horizon Scanning Can Give the Military a Technological Edge.' As of 6 August 2024: https://www.rand.org/pubs/commentary/2019/02/how-horizon-scanning-can-give-the-military-a-technological.html

14 TRL 'is a scale for measuring the maturity of a technology […] TRL describes the performance history of a given system, subsystem, or component relative to a set of levels first described at NASA headquarters in the 1980s.' See: National Aeronautics and Space Administration (NASA). 2020. 'Technology Readiness Assessment: Best Practices Guide.' As of 6 August 2024: https://ntrs.nasa.gov/citations/20205003605. There are nine TRL levels – at the first level are technologies at the stage of principles and concepts, and at the highest level are technologies successfully applied in the field.

15 Espacenet. n.d. 'Homepage.' As of 6 August 2024: https://worldwide.espacenet.com/; Patsnap. n.d. 'Homepage.' As of 6 August 2024: https://www.patsnap.com/

16 World Food Programme (WFP) Innovation Accelerator. 2024. 'About us.' As of 6 August 2024: https://innovation.wfp.org/about-us

17 ReliefWeb. 2024. 'Homepage.' As of 6 August 2024: https://reliefweb.int/

18 Global System for Mobile Communications Association (GSMA). 2024. 'Meet the start-ups of the GSMA Innovation Fund for Anticipatory Humanitarian Action.' As of 6 August 2024: https://www.gsma.com/solutions-and-impact/connectivity-for-good/mobile-for-development/gsma_resources/meet-the-start-ups-of-the-gsma-innovation-fund-for-anticipatory-humanitarian-action/

Creating Hope in Conflict: A Humanitarian Grand Challenge.[19]

This methodology yielded a longlist of 179 'signals' of emerging technologies that could impact the humanitarian sector over the next ten years. These signals were categorised as follows:

- **Components**, a constituent part of a technology that has no technological function in isolation;
- **Devices**, a singular technology made of multiple components;
- **Systems**, an integrated system of multiple interoperable devices; or
- **Applications**, a service or user interface built into a device or system.

The study team reviewed basic technical information about the technology, evidence of regional applications, and potential application(s) across humanitarian clusters for each signal.[20] Emerging technologies with potential to spill over from adjacent sectors into humanitarian activities (e.g. conflict prevention, development, peacebuilding) were included in the horizon-scanning activities. This was due to the potential technology crossover within the conflict-development nexus in which humanitarian action takes place.

Assessments of emerging technologies' potential applications were made based on the subjective professional judgements of the study team, drawing on the stated potential use cases of the technologies and evidence of their previous contextual applications in the humanitarian and other relevant sectors. Emerging technology signals were iteratively tagged based on their relevance to systemic challenges in the humanitarian sector.[21] These were identified through targeted desk research of academic and grey literature on these challenges and scoping interviews with humanitarian stakeholders (outlined in Section 2.1.1). These assessments were made based on the insights provided by scoping interviewees, or through subjective judgement of the study team drawing on evidence highlighting technologies' association with challenges.

The study team first classified all signals across the four above-mentioned categories and then conducted a thematic analysis to identify systems-level groupings for these signals. As a result of this iterative process, the study team identified 50 emerging technology areas (see Table 2.2 and Annex A). Emerging technology signals were grouped together where they had similar humanitarian use cases and functions (e.g. emerging technology signals relating to novel methods for producing food were grouped into 'advanced food production') and/or similar technical configurations (e.g. technologies utilising remote visualisation technologies were grouped into 'virtual and augmented realities').

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19 United States Agency for International Development (USAID).. 2024. 'Creating Hope in Conflict: A Humanitarian Grand Challenge.' As of 6 August 2024: https://www.usaid.gov/grandchallenges/humanitarian

20 The UN developed a clusters approach for humanitarian crises that encompass 11 areas: camp coordination and management; early recovery; education; emergency telecommunications; food security; health; logistics; nutrition; protection; shelter; and water, sanitisation and hygiene (WASH). See: United Nations High Commissioner for Refugees (UNHCR). 2023. 'Cluster Approach.' As of 6 August 2024: https://emergency.unhcr.org/coordination-and-communication/cluster-system/cluster-approach

21 In this context, where evidence suggests technologies could represent a significant cause of, or solution for, these challenges.

Table 2.2 Overview of technology areas identified through horizon scanning[22]

Emerging technology areas			
Advanced food production	Cyber-threat defence	Micro-energy solutions	Privacy-enhancing technologies
Advanced infrastructure component manufacturing	Dynamic/micro-internet access systems	Micro-finance and acute financial support	Rapid/micro-scale health diagnostics
Advanced shelter construction and defence	Edtech and remote learning	Migration and human movement monitoring	Remote sensing instruments
Advanced water treatment	Environmental observation systems	Modular transport infrastructure	Rescue robotics
Advanced wireless communication system	Food access and cooking tools	Multi-surface vehicles	Shelter cooling systems
Advanced wound care	Food nanotechnologies	Novel data analytics	Smart translation and communication tools
Agile cargo storage and delivery	Food testing and preservation	Novel energy security and efficiency technologies	Telemedicine
Automated disaster early-warning systems	Forensic investigative genealogy	Novel mental health treatments	Tissues and prosthetics manufacturing
Biohazard treatments	Goods and product tracking	Novel waste treatment systems	Unmanned aerial vehicles and drones
Biometrics and identity technologies	Health pathogen detection and treatment	Open information sharing, standards, platforms and protocols	Virtual and augmented realities
Blockchain and decentralised technologies	Humanitarian service aggregation and response coordination	Organisation resource management tools	Water harvesting
Blood treatment and delivery	Logistics and infrastructure optimisation	Peer-to-peer networks and citizen reporting platforms	
Camp monitoring systems	Medical manufacturing devices	Precision medicine	

Source: Study team analysis.

22 Each of the 50 technology areas listed in Table 2.2 is presented in more detail in Annex A, Table A.2. Technologies relating to AI and ML are explored through a dedicated UKHIH-funded project and are not within the scope of the present study.

2.2. Mapping humanitarian organisations and sectoral challenges

The study team conducted automatic reading across open web sources (e.g. company websites, news sites and blogs, social media, official sources) to map the humanitarian sector. Web reading used lexical analysis and topic modelling to identify organisations active across humanitarian sectors worldwide, including those active in low- and middle-income countries (LMICs).[23] Web reading also identified key terms, issues and technologies referenced by these organisations in their public websites and communications. The web-reading process involved the following steps:

1. **Crawling design and inputs.** Within the study team, an iterative process led to agreement on definitions, inputs, frames of reference, indicators and desired formats. Based on these, a list of relevant key words relating to the humanitarian sector was developed.
2. **Initial automated crawling.** This entailed initial crawling to obtain a baseline dataset, gathering information from key data sources, conducting discovery of new sources, and creating and presenting of a sample dataset for feedback to refine the scope of the crawling.
3. **Refined automated crawling.** This involved conducting a refined crawl based on internal review, conducting a deeper crawl of websites and social media to identify their relevance based on information provided there, validating data using other sources, and presenting an updated dataset with additional fields.
4. **Signal and indicator crawling.** This entailed, based on additional rounds of review, deeper crawling to gather signal-based information using bespoke language, crawling of additional sources to obtain signal data, matching of data and introducing additional fields in the dataset (binary markers[24] and web links to supporting evidence) to provide an updated sector dataset.
5. **Validation and data issue.** This involved an automated validation of data based on heuristics and checks/balances to challenge validity of results and spot inconsistencies, a manual review of sample results to ensure the relevance of results (context of textual evidence, recurrence, alignment with keywords), data cleansing, applying updates (where required, including plugging coverage gaps) and providing the final dataset, a methods note and user guidelines for further use by UKHIH.

These activities led to the following outputs:

1. **Humanitarian organisations dataset**: a database of humanitarian organisations, including classification into humanitarian and development organisations, classification based on their core activities, and contact details. From the initial web-reading activities that led to the identification of over 7,700 results, the study team conducted several rounds of review that led to the identification of

23 Lexical analysis refers to the process of splitting texts into tokens (such as words, phrases or sentences). Topic modelling is the use of a statistical model to identify latent topics in a text. See: Silge, Julia & David Robinson. 2024. 'Text Mining with R: A Tidy Approach.' As of 6 August 2024: https://www.tidytextmining.com/ and Jurafsky, Daniel & James H. Martin. 2024. *Speech and Language Processing: An Introduction to Natural Language Processing Computational Linguistics and Speech Recognition*. As of 6 August 2024: https://web.stanford.edu/~jurafsky/slp3/

24 Information identified through the crawling is coded through a binary system with two states (e.g. 0 or 1; on or off; high or low). See: DevX Editorial Staff. 2023. 'Binary Data.' As of 6 August 2024: https://www.devx.com/terms/binary-data/

other organisation and the classification of the database according to the following categories: 'core humanitarian organisations' (2,256), 'policy & research organisations' (435), 'development organisations' (4,108) and 'other organisations (4,353).

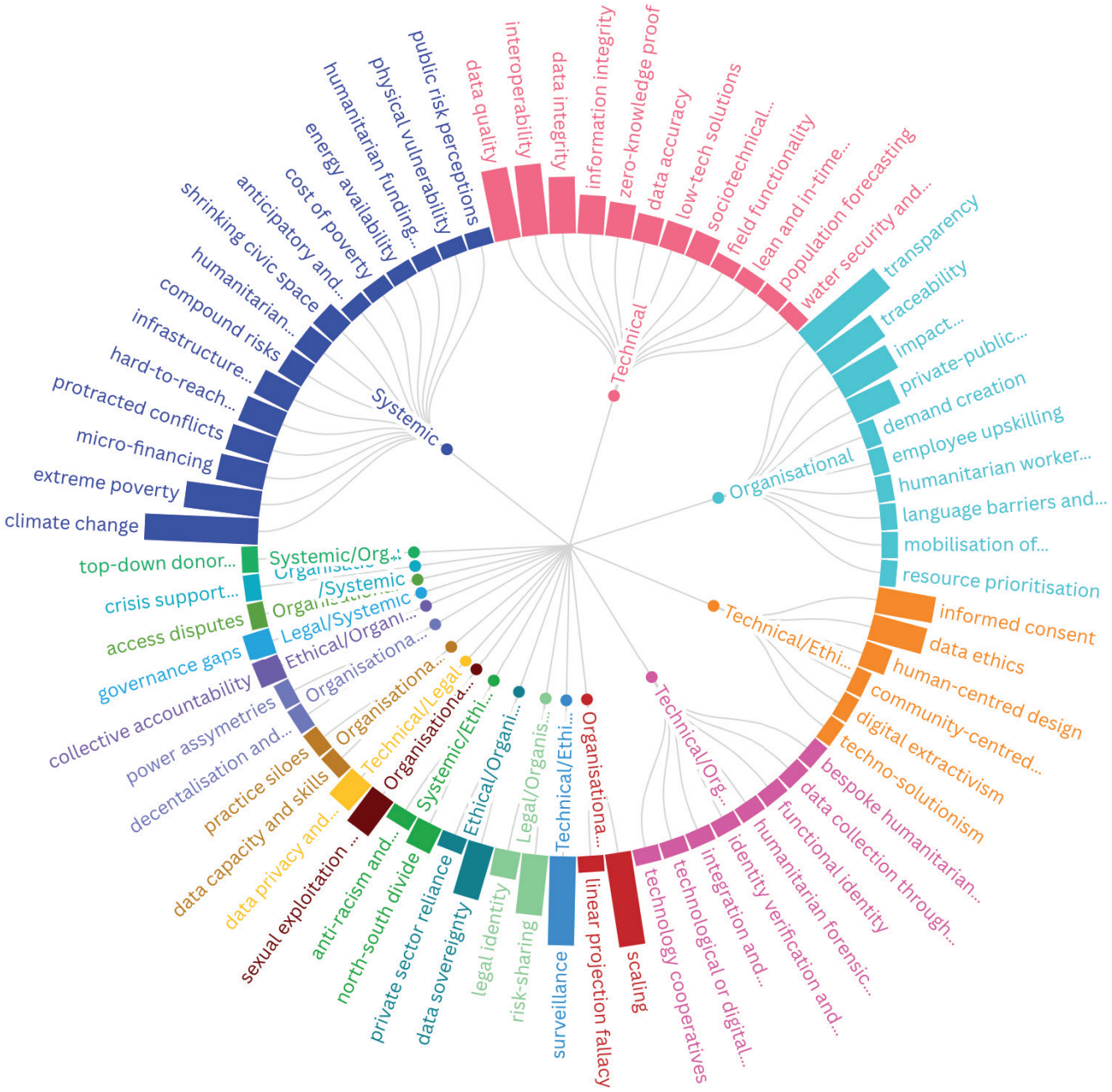
2. **Emerging technologies and humanitarian challenges**: a deep crawl of the humanitarian organisations dataset to identify emerging technologies and challenges mentioned by these organisations. Initial web-reading activities resulted in the identification of hundreds of technologies and challenges. Challenges distinguished between systematic, organisational, legal, technical or ethical issues. This taxonomy, providing a common language around humanitarian issues, was used to engage with participants in project workshops (see project Phase 2 in Section 3.2) and to ensure that we have a reasonably nuanced understanding of how and where challenges should be considered at different research stages. Systemic, organisational and legal challenges are treated as issues that technologies have the potential to help address (e.g. climate change and extreme poverty), while technical and ethical challenges typically relate to the risks and barriers related to deploying technologies (e.g. information integrity and interoperability).

Initial results of our web-crawling activities are presented in Figures 2.3 to 2.5. Figure 2.3 presents an overview of the signals of emerging technologies identified: items included in the middle ring represent groupings of system-level technologies, while items included in the outer ring represent exemplar applications and devices within the identified grouping. For example, in purple in the bottom right part of the figure cryptographically secured evidence, cryptosecure communications, data-anonymisation tools and privacy-preserving information-sharing services are grouped into privacy-enhancing technologies. Figure 2.4 presents the results of web-crawling activities in relation to humanitarian challenges, which are presented in the outer ring. These challenges are also grouped in the middle ring based on the taxonomy of challenges identified by the study team (i.e. systemic, organisational, legal, technical, ethical), either against one or more challenges. Figure 2.5 presents web-crawling results associating technologies with humanitarian challenges. These technologies and challenges were subsequently refined and mapped into a consolidated list of 50 technology areas and 64 humanitarian challenges were subsequently (see Annex A).

Figure 2.3 Emerging technologies identified through web reading

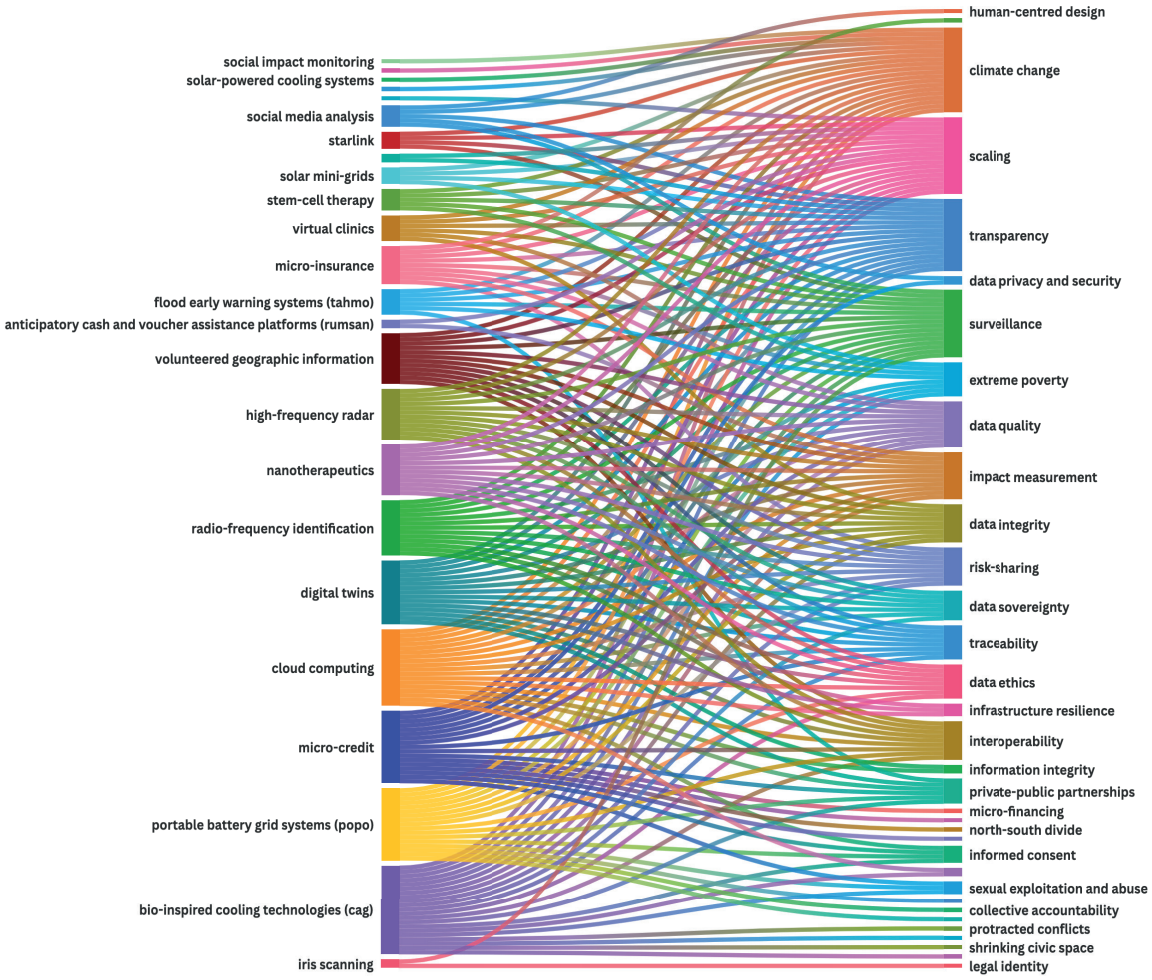
Source: Study team analysis.

Figure 2.4 Humanitarian challenges identified through web reading



Source: Study team analysis.

Figure 2.5 Technology–challenge relationships identified through web reading



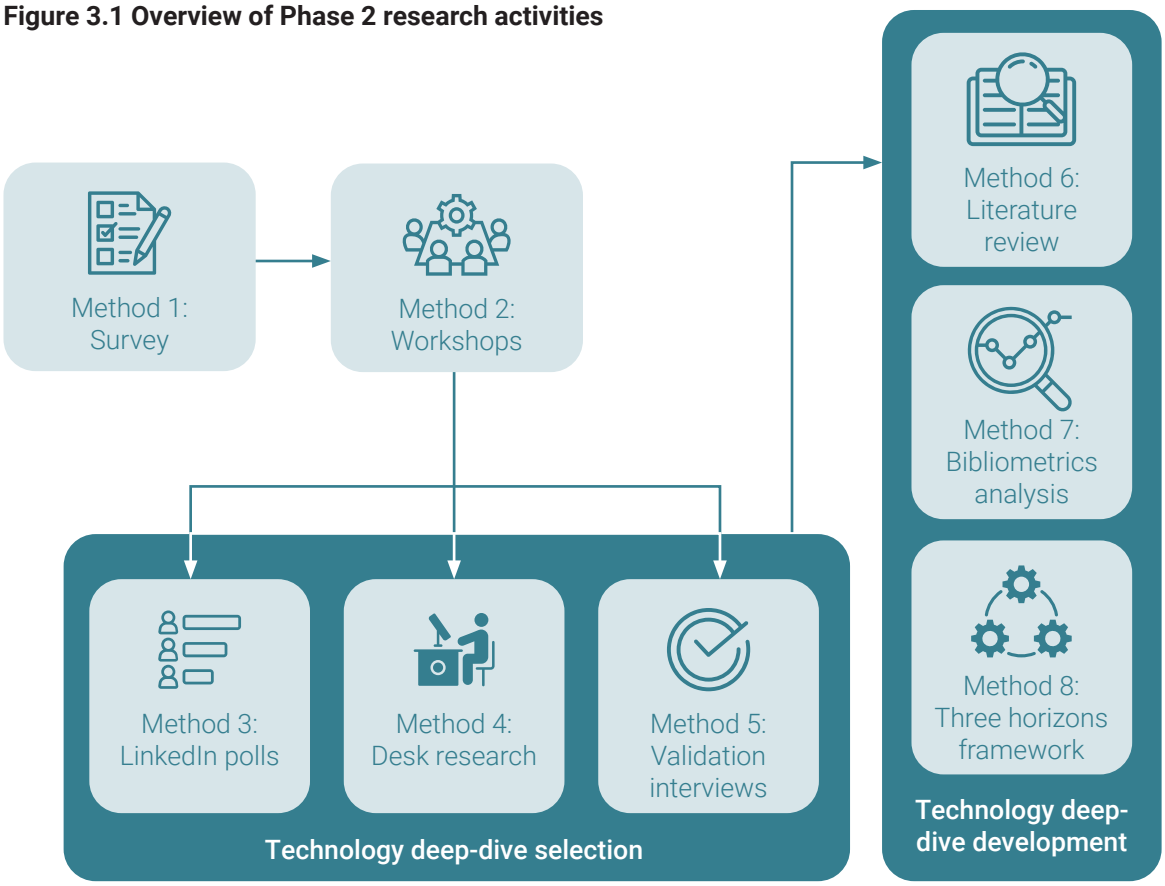
Source: Study team analysis.

These outputs provided the client with a dataset of organisations conducting humanitarian-related operations, reflecting web-reading results relating to the application of emerging technologies in the humanitarian sector. The study team used these initial outputs to support the Phase 2 activities and the development of the technology deep dives (see Chapter 3).

Chapter 3. **Phase 2 activities**

Upon the completion of Phase 1 activities and the identification of potential technology areas to be adopted and used within the humanitarian sector, Phase 2 activities started with selecting priority technology areas to be further explored through deep dives. The study team aimed to understand the ethical and implementation challenges of deploying emerging technologies in humanitarian work, and to learn from the perspectives of humanitarian practitioners, particularly those working in LMICs. Phase 2 activities are summarised in Figure 3.1 below.

Figure 3.1 Overview of Phase 2 research activities



Source: Study team analysis.

3.1. Surveying the use of emerging technologies in the humanitarian sector

The study team first conducted a survey of humanitarian practitioners focused on the impact of applications of emerging technologies within the sector. The survey aimed to:

1. Understand and define trends in the adoption and use of emerging technologies within the humanitarian sector;
2. Identify key emerging technologies that could strengthen humanitarian practice, and understand their risks and opportunities;
3. Elicit views on challenges within the humanitarian sector and explore emerging technologies that could help address them;
4. Identify the potential benefits and opportunities, barriers and challenges (including moral or ethical ones), as well as the potential impact and implications, of the adoption and use of these technologies on the humanitarian sector; and
5. Form the basis for subsequent project activities in Phase 3 (see Chapter 4).

The survey was designed by the study team and an outline emphasising the scope was shared with UKHIH, as presented in Box 3.1. It was made clear to participants that AI and ML were outside of the scope of this project, given the existence of a dedicated AI-centred project also funded by UKHIH. The survey was distributed through an online platform and participants were contacted using the contact emails identified through mapping activities (see Section 2.2). Given the high numbers of contacts identified in the humanitarian organisations, the study team prioritised 'Person 3' contacts following a manual review of results. The survey was also distributed by Athena Infonomics and UKHIH via social media, Phase 1 interviewees and humanitarian networks. The survey remained open for two weeks and a total of 29 fully completed responses were gathered (with 189 partial responses).

Participation rates were lower than expected. This may be due to several factors including: (i) the limited availability of humanitarian stakeholders to take part in a survey; (ii) an extensive use of surveys within the humanitarian sector, creating a form of survey fatigue; and (iii) limited familiarity and/or interest in emerging technologies in the sector among the people contacted. Due to the low participation rate, respondents' answers were not considered to be representative by the study team, who conducted additional activities to validate results and confirm the technology areas to be developed in the deep dives (see Section 3.3).

Box 3.1 Survey outline

1. Survey introduction and privacy policy

Many thanks for taking part in this survey on emerging technologies in the humanitarian sector. Please find below some information on the project and on the survey itself.

Project context and purpose

RAND Europe is a not-for-profit research organisation that helps to improve policy and decision making through research and analysis (www.randeurope.org). RAND Europe, together with glass.ai and Athena Infonomics, is currently conducting a project for the United Kingdom Humanitarian Innovation Hub (UKHIH) that seeks to:

- Understand and define trends in the adoption and use of emerging technologies within the humanitarian sector;
- Identify key emerging technologies that could strengthen humanitarian practice through an online survey;
- Scope guidance and new programmes to support humanitarian actors to engage with emerging technologies.

Please see a letter of introduction from the UK Humanitarian Innovation Hub linked **here**.

Please note this survey is for humanitarian practitioners only. We broadly define humanitarian practice as work intended to save lives, alleviate suffering and maintain human rights during and after man-made crises and disasters caused by natural hazards, as well as to prevent and strengthen preparedness for such situations. Humanitarian practice also adheres to principles such as humanity, impartiality, neutrality and independence (more details **here**).

Survey overview

We are contacting you to request your participation in the survey based on your experience and expertise in the humanitarian sector. Your answers to the survey will help us to understand and identify which emerging technologies could be key to strengthening humanitarian practice. To do so we are looking to elicit your views on existing challenges within the humanitarian sector and exploring emerging technologies that could help address them. Specifically we are looking to identify the potential benefits and opportunities, barriers and challenges (including moral or ethical ones) as well as the potential impact and implications of the adoption and use of these technologies on the humanitarian sector.

Please note that artificial intelligence (AI) and machine learning (ML) are outside of the scope of this project, as UKHIH are conducting a specific project focusing on AI. This project focuses on other emerging technologies in the humanitarian sector with a low technology readiness level (TRL). A list of the technologies we are researching, their definitions and examples are available in Annex A.[25]

Questions marked with * are mandatory. We expect that the survey will take 20–30 minutes to complete.

Privacy policy

As part of this study, we are contacting subject-matter experts to provide expert opinion to help inform our analysis. The information you provide as part of the study forms part of the research data. Your personal data (name, position and organisation, e-mail address) are being collected as part of the process of scheduling and carrying out this survey, and for follow-up clarifications (if necessary). The information collected during this survey will be used only for research in relation to the subject matter of the study.

What is the legal basis for processing activities?

The legal basis for processing your personal data, and contacting you, is that it is in our legitimate interest to allow you to participate in this project. Your interests are not affected in any way, as our default position is that your personal data will not be linked to your responses, so any information you provide will be unattributable.

25 See Annex A, Table A.2.

About the collected data and its processing and storage

The data will be securely stored digitally. Access to the data is controlled on a 'need to know' basis and only available to the study team. All data provided will be processed in accordance with standards of the EU's General Data Protection Regulation (GDPR). All personally identifiable data collected as part of this project will be deleted one year after the end of the project.

Your rights

RAND Europe operates in accordance with the Data Protection Act 2018 and EU law including GDPR. You are provided with certain rights that you may have the right to exercise through us. In summary those rights are:
To access, correct or erase your data;
To object to the processing of your data;
To request that our processing of your data is restricted, or to withdraw consent.

If you wish to exercise any of these rights please contact the RAND Europe Data Protection Officer by email at REdpo@randeurope.org or by writing to Data Protection Officer, RAND Europe, Eastbrook House, Shaftesbury Road, Cambridge, CB2 8BF, UK, referring to 'Emerging Tech Foresight initiative' as the subject. You also have the right to contact the Information Commissioner's Office in the UK if you have concerns about the processing of your data by RAND Europe.

Who am I to contact for more information about this project?

If you have any query or concern about any aspect of this study, please contact the study team at humanitarianemtech@randeurope.org.

By participating in this survey, you acknowledge and agree to us processing your data according to the process outlined above.

2. Survey

Key humanitarian challenges

Q1. From your experience, what do you see as the main operational challenges facing the humanitarian sector over the next 10 years?* (*Open*)

Emerging technology applications

Q2. In your opinion, what new and emerging technologies are likely to have the greatest impact on the operational challenges you've described in the previous question?* *If possible, please provide relevant application(s) of technologies in the humanitarian sector which you have worked with or are aware of. (Open)*

Emerging technologies of interest

Q3. Among the following technology areas, which do you believe will have the biggest impacts on humanitarian operations over the next 10 years? Please select up to 3 technologies.* *For definitions of technologies, please refer to the accompanying emerging humanitarian technologies document provided by the research team.*[26]

Adoption of emerging technologies

Q4. Among the following emerging technology areas, which ones do you believe humanitarian actors will require the most support and guidance to responsibly adopt over the next 10 years? Please select up to 3 technologies.*[27]

Understanding the opportunities and risks of [technology area(s) selected in Q4] for the humanitarian sector

Q5. On a scale of 1 to 4, how significant do you think the positive impacts of [technology area(s) selected in Q4] will be on humanitarian operations globally over the next 10 years? *(List: 1 = No positive impacts; 2 = Limited positive impacts; 3 = Significant positive impacts; 4 = Major positive impacts (i.e. essential to operations); Don't know)*

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26 See Annex A, Table A.2.

27 List of 50 technology areas; see Table 2.2.

Q6. Please provide examples of the potential positive impacts these technologies could have on the humanitarian sector.* (*Open*)

Q7. On a scale of 1 to 5, how difficult will it be for transnational humanitarian actors and affected communities in high-income countries to adopt and use these technologies over the next 10 years?* (*List: 1 = Not at all; 2 = To a limited extent; 3 = To a moderate extent; 4 = To a significant extent; 5 = Not possible; Don't know*)

Q8. On a scale of 1 to 5, how difficult will it be for humanitarian actors and affected communities in low- and middle-income countries (LMICs) to adopt and use these technologies over the next 10 years? Please see the OECD definition of LMICs **here**. (*List: 1 = Not at all; 2 = To a limited extent; 3 = To a moderate extent; 4 = To a significant extent; 5 = Not possible; Don't know*)

Q9. What type(s) of mitigation strategies, guidance or support could be used to overcome the challenges related to the adoption and use of these technologies? (*Open*)

Q10. In your opinion, which country, countries or region(s) will realise the majority of the positive benefits from these technologies, if any?* (*Open*)

Q11. In your opinion, which country, countries or region(s) are likely to face the most challenges in the adoption and use of these technologies in humanitarian activities?* (*Open*)

Q12. In your opinion, what are the potential ethical, social or legal issues and risks that could arise in relation to the use of these technologies in the humanitarian sector over the next ten years?* (*Open*)

Q13. In your opinion, are there any ethical, social or legal issues and risks associated with the use of these technologies that are particularly relevant in low- and middle-income countries (LMICs)? (*Open*)

Q14. What type(s) of mitigation strategies, guidance or support could be used to overcome these ethical, social and legal challenges? (*Open*)

Questions Q5 to Q14 were presented to participants based on the number of technology areas selected in Q4.

Respondent information and participation in future research activities in the humanitarian sector

Q15. What region(s) do you primarily work in? Please select all that apply.* (*List: Africa; Americas; Asia; Europe; Oceania; Other, please specify*)

Q16. Do you work directly in low- and middle-income countries (LMICs)? (*List: Yes; No*)

Q17. What humanitarian cluster area(s) do you primarily work in? Please select all that apply.* Follow this **link** for more details on the UN Cluster Approach. (*List: Camp coordination and management; Early recovery; Education; Emergency Telecommunications; Food Security; Health; Logistics; Nutrition; Protection; Shelter; Water, Sanitisation and Hygiene*)

Q18. What is your job title? (*Open*)

Q19. What kind of humanitarian organisation or institution do you work for?* (*List: National government or public sector; Charity or non-governmental organisation; Technology service provider; Other*)

Q20. In your professional role(s), what is your relationship to technologies in the humanitarian sector? Please select all that apply.* (*List: Developer of technologies; Purchasing or procurement of technologies; End-user; Governance and oversight of technologies; None of the above; Other*)

Q21. Would you like to be contacted about participating in future phases of this research?* If so, please insert your email here. (*List: Yes; No*)

Q22. Would you like to be kept informed about the outputs of this work?* If so, please insert your email here. (*List: Yes; No*)

Q23. How did you find out about this survey? (*Open*)

Thank you page

Thank you for completing this survey.

3.2. Emerging Technology Ethics Workshops

To supplement the survey, two workshops were organised by the study team and held on 29 February and 5 March 2024. Across the workshops, 24 humanitarian stakeholders, including representatives from LMICs, discussed opportunities for addressing the ethical implications of emerging technologies (see Figures 3.2 and 3.3 below).

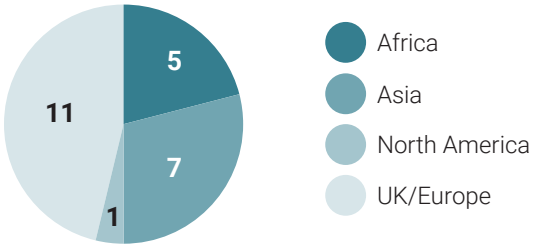
Specifically, the purpose of these workshops was to:

1. Stimulate discussion on challenges relating to the potential issues associated with the development and use of emerging technologies in the humanitarian sector, with a particular focus on ethical issues; and
2. Explore opportunities for new guidance, 'futures' research projects, and partnerships that could help to address the issues identified.

To identify workshop participants, the study team reached out to stakeholders engaged in Phase 1 activities, conducted targeted desk searches and sought recommendations from individual stakeholders and UKHIH. Specifically, individuals working for humanitarian organisations and having relevant experience with emerging technologies were identified and invited to the workshops. Calls for the workshop were also shared by Athena Infonomics and UKHIH through social media.

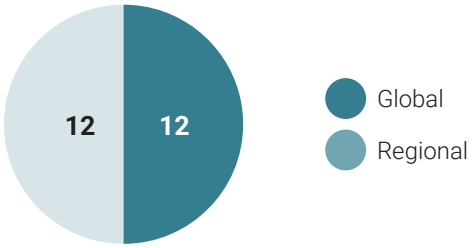
Both workshops were held online via Microsoft Teams. The study team also used online whiteboards to facilitate and support discussions among participants.

Figure 3.2 Workshop participation by geography



Source: Study team analysis.

Figure 3.3 Workshop participation by type of organisation represented



Source: Study team analysis.

Each workshop consisted of an introduction, in which participants were introduced to the project, its aims and its context, and two breakout sessions followed by plenary discussions with the whole group. This was intended to enable open discussion in smaller groups. Table 3.1 below presents the agenda developed for both workshops.

The workshops enabled fruitful and in-depth discussions regarding humanitarian technologies as well as the wide-ranging ethical implications their adoption and use may raise in coming years, both across the sector and in specific contexts (e.g. technology 'extractivism' and colonialism, digital harm).[28] Initially, the workshops had been envisaged by the study team as an opportunity to further discuss technology areas arising from survey

28 Discussions on emerging technologies included remote sensing technologies, advanced wound care, agile cargo storage, camp monitoring systems, edtech and remote learning, novel mental health treatments, and unmanned aerial vehicles and drones (RAND Europe workshops, 29 February and 5 March 2024).

results. Given the lower-than-expected survey response rates, however, discussions were broadened to consider the 50 technology areas. The list of technology areas and their definitions was shared with workshop participants in advance.

Table 3.1 Workshop agenda

Timing (GMT)	Agenda item and description
09:30–09:35	Welcome and introductions
09:35–09:40	Workshop introduction – the study team presented the aims and structure of the workshop, as well as the rules of engagement
09:40–09:45	Project overview – the study team provided an overview of the overall project and activities to be conducted
09:45–10:10	Introduction to Breakout 1 (plenary) – the study team provided an introduction to the 'common humanitarian values framework' to be used during the breakout
10:10–11:00	Breakout 1: Emerging technologies and humanitarian values – the breakout session started with an ice-breaker and short introduction of each participant. Participants then engaged in discussions on future use cases for technologies across the humanitarian clusters and explored how these use cases could challenge humanitarian values
11:00–11:15	Break
11:15–11:20	Breakout 1 feedback session (plenary) – a representative from each breakout group shared an overview of the discussions with other participants
11:20–11:25	Introduction to Breakout 2 (plenary) – the study team provided an overview of Breakout 2 activities, designed to build on Breakout 1 discussions
11:25–12:15	Breakout 2: Navigating emerging technology challenges – participants discussed potential humanitarian challenges associated with the technology areas identified and discussed during Breakout 1. Solutions to the identified challenges and their potential impacts across the humanitarian sector were also discussed
12:15–12:25	Breakout 2 feedback session (plenary) – a representative from each breakout group shared an overview of the discussions with other participants
12:25–12:30	Workshop wrap-up and next steps

3.3. Additional validation activities

Following the survey and workshop activities and based on the numerous technology areas discussed by participants and survey respondents, the study team, in consultation with UKHIH, conducted two additional engagements based on initial findings. The first of these consisted of a series of four polls published on LinkedIn by UKHIH in March 2024, as presented in Box 3.2 below. Responses to these polls remained low (between 6 and 16). Therefore, in consultation with UKHIH, the study team conducted additional targeted engagement with stakeholders from the technology areas that emerged before finalising the list of deep-dive areas.

Box 3.2 Overview of LinkedIn polls

Poll 1

In which of these areas relating to coordination do humanitarians need more support to responsibly adopt emerging technologies?

- Security services
- Digital communication platforms
- Tracking of goods

Poll 2

In which of these areas relating to community needs do humanitarians need more support to responsibly adopt emerging technologies?

- Food and water security
- Energy solutions
- Health treatment
- Financial support

Poll 3

In which of these areas relating to crisis response do humanitarians need more support to responsibly adopt emerging technologies?

- Natural disaster prediction
- Addressing rights violations
- Accessing risky environments

Poll 4

In which of these areas relating to infrastructure do humanitarians need more support to responsibly adopt emerging technologies?

- Camp management
- Novel transport systems
- Next-generation manufacturing

3.3.1. Prioritising technology areas

Based on these activities, the study team selected the following technology areas for the deep dives.[29]

- **Camp monitoring systems,** comprising systems used to monitor and regulate access to and from refugee camps and detention centres as well as other types of temporary settlements established by humanitarian actors in response to a crisis or disaster in proximity to affected populations (e.g. refugees, internally displaced persons (IDPs)).[30]
- **Privacy-enhancing technologies,** understood as those systems that contribute to the protection of personal and sensitive data, including, for example, encryption or tools to ensure that data is anonymised and cannot be further exploited to harm individuals or groups.[31]
- **Service aggregation and coordination systems,** understood as those systems used by humanitarian actors to gather and exploit data, exchange information and/or resources, and support collaboration and strengthen transparency and accountability within the humanitarian sector.[32]
- **Advanced manufacturing systems,** encompassing the suite of emerging material production technologies and systems that offer performance improvements relative to conventional manufacturing approaches by enabling greater geometric complexity of products, improving energy and material usage efficiency, reducing infrastructure and resource needs for deployment, or enabling the use of a broader range of feedstock materials.[33]
- **Disaster early-warning systems,** with a particular focus on their potential application in low-resource contexts.

3.4. Technology deep dives

Following the research activities conducted in the first phase of the project, the five technology areas presented in the previous section were selected by the study team to be further explored based on their potential impact on humanitarian activities out to 2030. This section presents how these technologies were explored in greater detail.

3.4.1. Developing technology deep dives

For each of the five technology areas, the study team conducted additional targeted searches to supplement data gathered during Phase 1 activities as well as the survey and workshops conducted under Phase 2. Searches were conducted using databases of academic

29 Paillé, Pauline, James Besse, Hampton Toole, Chryssa Politi, Shruti Viswanathan, Eunice Namirembe, Jyoti Nayak, Sergi Martorell, Iain McLaren, Christopher Tyson, Charlie Wilkening & Jacob Ohrvik-Stott. 2024. *Emerging technologies in the humanitarian sector: Technology Deep Dive Series*. Santa Monica, Calif.: RAND Corporation. RR-A3192-1. As of 17 October 2024: www.rand.org/t/RRA3192-1

30 Karaiskou, Alexandra. 2023. 'Drones & Artificial Intelligence at Greece's high-tech borders.' *Homo Digitalis*. As of 6 August 2024: https://homodigitalis.gr/en/posts/131019/

31 Organisation for Economic Cooperation and Development (OECD). 2023. 'Emerging privacy enhancing technologies: current regulatory and policy approaches.' OECD *Digital Economy Papers* 351. As of 6 August 2024: https://www.intgovforum.org/sites/default/files/webform/igf_2023_open_forums_town_hall_s/243938/bf121be4-en.pdf

32 Nesta. 2021. 'Collective crisis intelligence for frontline humanitarian response.' As of 6 August 2024: https://www.nesta.org.uk/report/collective-crisis-intelligence-frontline-humanitarian-response/

33 Science Direct. 2024. 'Advanced Manufacturing.' ScienceDirect.com. As of 6 August 2024: https://www.sciencedirect.com/topics/engineering/advanced-manufacturing

papers, such Google Scholar and OpenAlex, patent databases, such as Espacenet and Patsnap,[34] and websites for humanitarian innovation hubs, accelerators and funds including the World Food Programme Innovation Accelerator,[35] ReliefWeb,[36] the GSMA Innovation Fund for Anticipatory Humanitarian Action[37] and Creating Hope in Conflict: A Humanitarian Grand Challenge.[38] Papers were reviewed to identify the specific humanitarian applications of each emerging technology area (e.g. within the broad category of advanced manufacturing, what kinds of specific applications existed within humanitarian work), key definitions, the level of technology maturity as well as the barriers and enablers to their adoption, and/or related challenges and opportunities. These targeted searches aimed to understand both the current use of these technology areas in the humanitarian sector as well as their potential future developments out to 2030.

Alongside this literature review, the team conducted a review of the interview notes and transcripts as well as the notes from the ethics workshops. This review was used to inform the deep dives into each technology area with the perspectives of participants. Specifically, the team identified material in the interview and workshop transcripts that dealt with specific emerging technologies participants expected would be relevant for the sector, along with anything they said about barriers, enablers, risks and opportunities related to these technologies. These findings were incorporated into the deep dives by informing the study team choices of specific technologies to include, as well as assessment of their maturity and the associated barriers, enablers, risks and opportunities for each. To capture these insights, the study team used a 'three horizons' framework to capture relevant data across research activities.

The 'three horizons' framework (see Figure 3.4) distinguishes between the present (Horizon 1) and the long-term future (Horizon 3). Horizon 2, also designated as the transitory phase, can be used to identify the factors and changes that need to occur to enable or prevent the materialisation of Horizon 3.

34 Espacenet. n.d. 'Homepage.' As of 6 August 2024: https://worldwide.espacenet.com/; Patsnap. n.d. 'Homepage.' As of 6 August 2024: https://www.patsnap.com/

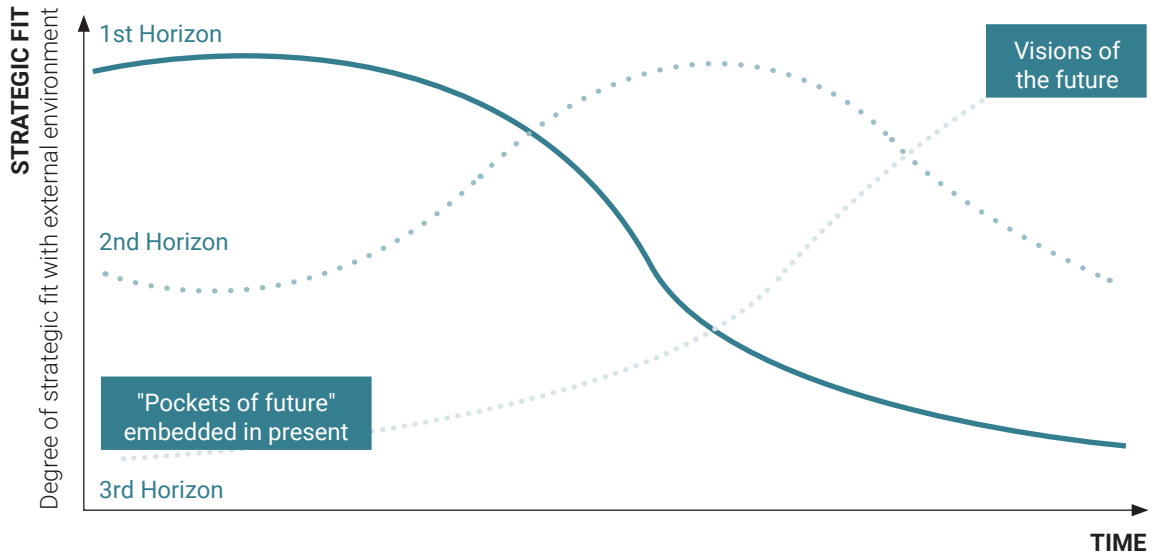
35 World Food Programme (WFP) Innovation Accelerator. 2024. 'About us.' As of 6 August 2024: https://innovation.wfp.org/about-us

36 ReliefWeb. 2024. 'Homepage.' As of 6 August 2024: https://reliefweb.int/

37 Global System for Mobile Communications Association (GSMA). 2024. 'Meet the start-ups of the GSMA Innovation Fund for Anticipatory Humanitarian Action.' As of 6 August 2024: https://www.gsma.com/solutions-and-impact/connectivity-for-good/mobile-for-development/gsma_resources/meet-the-start-ups-of-the-gsma-innovation-fund-for-anticipatory-humanitarian-action/

38 United States Agency for International Development (USAID). 2024. 'Creating Hope in Conflict: A Humanitarian Grand Challenge.' As of 6 August 2024: https://www.usaid.gov/grandchallenges/humanitarian

Figure 3.4 Overview of the 'three horizons' framework



Source: Adapted from Curry, Andrew & Anthony Hodgson. 2008. 'Seeing in Multiple Horizons: Connecting Futures to Strategy'. Journal of Futures Studies*, 13(1): 1-20. As of 6 August 2024: https://jfsdigital.org/wp-content/uploads/2014/01/131-A01.pdf*

Technologies were placed into each horizon based on the level of maturity described by participants and in papers reviewed for the study. Technologies placed in Horizon 1 were identified based on references to existing deployment in the humanitarian sector by interviewees, workshop participants and the literature. Horizon 2 was slightly more speculative, with technologies placed in this category already finding some foothold in the sector or in other areas, but still facing significant barriers or challenges to adoption. The decision to place certain technologies in Horizon 3 was far more speculative, with the team looking for often weak signals of newly emerging technologies that could offer value for humanitarian work.

3.5. Web-reading taxonomy terms for deep-dive areas

For each of the deep-dive areas, the study team also leveraged glass.ai's AI-enabled web-reading capabilities.

This iterative process followed a three-step approach:

- **Step 1 – Initial deep crawl.** Building on initial mapping activities conducted in Phase 1 (see Section 2.2), a deep crawl of the broad humanitarian organisations dataset was conducted to match to a seed taxonomy of emerging technologies and challenges, clustering the results to identify further emerging technologies and challenges.

- **Step 2 – Targeted deep crawl.** Following Phase 1 activities, the deep crawl was run again with a specific focus on these areas to produce an aggregate summary of the technology areas and humanitarian challenges identified. This second step was conducted against the list of 50 technology areas developed by the study team at the start of Phase 2.
- **Step 3 – Deep-dive-specific deep crawl.** Finally, a deep crawl was run on the humanitarian organisations dataset looking for the five emerging technologies prioritised for the deep dives, using a combination of keyword-based taxonomy and semantic categorisation of mentions within a humanitarian context.

For each of the deep-dive areas, two outputs were produced: (i) a list of terms associated with each prioritised emerging technology area; and (ii) a map of the countries in which each prioritised emerging technology area was mentioned the most by humanitarian organisations. These results and the web-reading taxonomy are presented in Annex B.

Chapter 4. **Phase 3 activities**

The final phase of the project involved the development of two outputs:

- Recommendations for guidance accompanying the roll-out of emerging technologies by humanitarian actors; and
- A proposal for a foresight initiative for emerging technologies in the humanitarian sector.

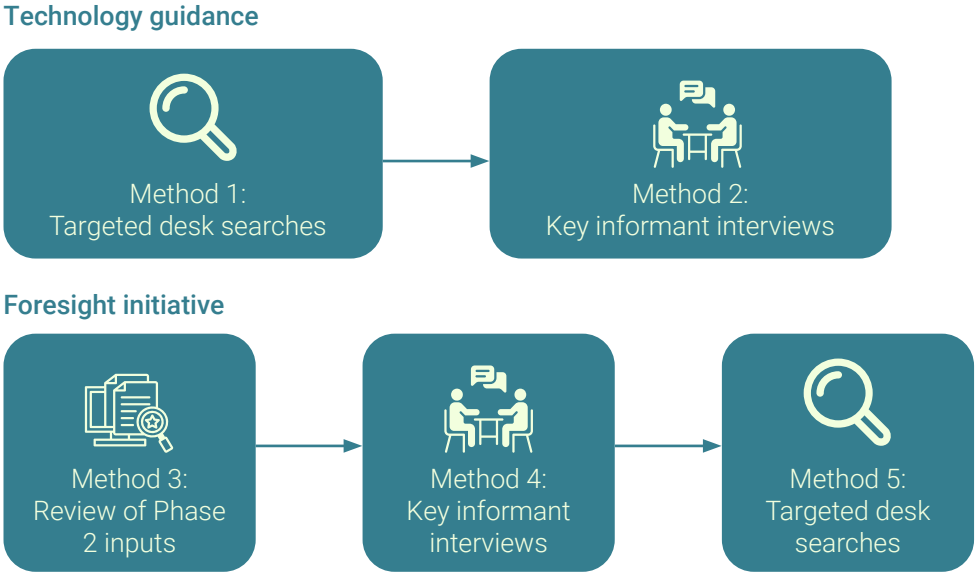
To support the development of these outputs, the study team conducted the activities outlined in Figure 4.1.

4.1. Technology guidance

Based on previous project activities and to support an increased use of emerging technologies across the humanitarian sector, the study team aimed to produce a comprehensive process for humanitarian practitioners to navigate decision making for emerging technology programmes. Throughout project activities, the study team identified opportunities, risks and challenges associated with emerging technologies across different humanitarian contexts that informed activities related to the development of useable guidance for the sector.

To prepare the technology guidance, the study team examined existing guidance for emerging technologies in the humanitarian sector through targeted searches to better understand the need for guidance and the existing gap in this space. Documents consulted included guidance produced by humanitarian

Figure 4.1 Overview of Phase 3 research activities



Source: Study team analysis.

organisations, including NGOs, innovation hubs and accelerators, and UN agencies, for the purpose of supporting broad technology use within the sector. The study team built on this review of existing guidance by looking at challenges associated with specific emerging technologies across different humanitarian contexts identified in previous project phases, such as the workshops, horizon scanning and technology deep dives.

To support their production of a useable guidance document for humanitarian-sector stakeholders, RAND Europe and Athena Infonomics identified participants for user research interviews. User research consisted in this case of interviews with humanitarian stakeholders to better understand their needs and practices with respect to emerging technologies. These interviews supported the participation-led approach adopted by the study team to develop bespoke guidance for humanitarians based on experience across the sector.

The study team particularly sought to include stakeholders working in LMICs, in alignment with the overarching aims of the project. Additionally, the study team engaged with UKHIH and the humanitarian network NetHope to elicit suggestions for potential participants and contacted survey participants who had expressed an interest in participating in additional project activities. Two semi-structured Phase 3 interviews were conducted by the study team between March and April 2024 (see Table 4.1).

4.2. Foresight initiative

In parallel to the development of the technology guidance, the study team also conducted activities to develop a proposal for a foresight initiative for the adoption of responsible technologies in the humanitarian sector. To do so, the study team adopted a mixed-method approach (see Figure 4.1) comprising a review of insights gathered in previous project activities (i.e. workshops, survey results), three key informant interviews with humanitarian foresight specialists, and targeted desk searches. The two workshops engaging humanitarians with the ethical implications of emerging technologies (see Section 3.2) were especially valuable for informing the proposed foresight initiative. While discussions did not exclusively or explicitly focus on futures and foresight programmes, some insights were relevant to technology foresight – for example, where humanitarians highlighted a need for support to anticipate sociotechnical risks of emerging technologies.

The study team contacted potential interviewees for the foresight interviews simultaneously to stakeholders for the user research interviews (see Section 4.1). A similar semi-structured approach was used and the study team conducted three interviews via Microsoft Teams in March 2024.

Table 4.1 Overview of user research interviewees

Date	Name	Affiliation
26/03/2024	Isaac Bencomo	Regional Duty of Care Advisor, Latin America & RAI US (interim), International Rescue Committee
02/04/2024	Eugenia Ollario	Programme Manager, Responsible Data for Children

Box 4.1 User research interview protocol

Part 1 – Introduction

Q1. Can you tell us about yourself and your current role?

a. Follow up: What region(s) do you primarily work in?

b. Follow-up: Do you work in any specific humanitarian cluster or clusters? Prompts: health, education, shelter, emergency telecoms, protection, WASH, etc.?

Q2. What are your motivations for working in the humanitarian sector?

Part 2 – Current practice and user needs

Q3. What does a typical working week look like for you?

a. Who do you typically work with?

b. What aspects of your work do you most and least enjoy?

Q4. What's your relationship to technologies in your work?

a. Are you responsible for deciding what technologies your organisation uses?

b. Do you have any experience of designing or making technologies?

c. Are there any emerging technologies you're particularly excited or concerned about?

Q5. What are the main challenges for you in your work?

a. Are they specific to your work or general to the humanitarian sector?

b. What role do technologies play in exacerbating or addressing these challenges?

Part 3 – Opportunities for meeting user needs

Q6. How do you approach navigating the challenges you've just described?

a. Where do you go to for support?

b. Are there any good practice lessons you think others could learn from?

Q7. Thinking about the development and adoption of new technologies in the humanitarian sector, where do you think support and guidance would be most helpful?

a. Are there any areas where guidance wouldn't be helpful?

b. Are there areas where there is already a lot of available guidance?

Q8. What forms of guidance do you think are most effective for supporting the humanitarian sector?

a. How does written guidance compare to other mediums?

b. How important are case studies and tangible examples of humanitarian work?

Q9. Can you point to any examples of guidance for the humanitarian sector that you think are especially good?

Part 4 – Conclusions and next steps

Q10. Is there anything you'd like to address that we haven't spoken about?

Q11. Do you have any questions for me?

Thank you for your time.

Box 4.2 Foresight interview protocol

Part 1 – Introduction

Q1. Can you tell us about yourself, your current role and wider experience relating to futures and foresight?

a. Follow up: Could you tell me about some examples of the futures and foresight projects you have worked on?

b. Follow up: What region(s) have these projects focused on?

c. Follow-up: Do you work in any specific humanitarian cluster or clusters? Prompts: health, education, shelter, emergency telecoms, protection, WASH, etc.?

Q2. What are your motivations for working in futures and the humanitarian sector?

Part 2 – Current practice of humanitarian foresight

Q3. How do you use futures and foresight in your work?

a. What methodologies do you commonly use?

b. Which humanitarian topics do you specialise in?

c. Do you use any supporting tools or technologies?

Q4. Which parts of the humanitarian sector have you worked with, or for?

a. Who are your typical target audiences?

b. Who do you collaborate with to deliver programmes?

Q5. What are the main challenges for researching emerging humanitarian technologies and trends?

a. Are they specific to your work or general to the humanitarian sector?

Part 3 – Opportunities for meeting user needs

Q6. How do you approach navigating the challenges you've just described?

a. Where do you go to for support?

b. Are there any good practice lessons you think others could learn from?

Q7. Thinking about the development and adoption of new technologies in the humanitarian sector, where do you think futures and foresight work can be most helpful?

a. Are there any areas where it wouldn't be helpful?

b. Are there areas where there is already a lot of available guidance?

Q8. What types of futures and foresight work do you think could most benefit the humanitarian sector?

a. What methodologies and tools does this relate to?

b. What thematic areas would be most helpful to focus on?

c. What networks, stakeholders and public communities do you think should be involved?

Q9. Can you point to any examples of futures and foresight work done by others which you think is especially good?

Part 4 – Conclusions and next steps

Q10. Is there anything you'd like to address that we haven't spoken about?

Q11. Do you have any questions for me?

Thank you for your time.

Table 4.2 Overview of foresight interviewees

Date	Name	Affiliation
07/03/2024	Dr Wendy L. Schultz	Director, Jigsaw Foresight & Director, Infinite Futures
08/03/2024	Ben Holt	IFRC, Solferino Academy
13/03/2024	Aarathi Krishnan	Global Intelligence Futures and Risk Anticipation Expert

Following the collation of relevant insights from these interviews and previous project research phases, targeted desk research of academic and grey literature and humanitarian organisation websites was conducted to:

- Validate interview insights relating to potential opportunities for technology foresight in the humanitarian sector, including to identify examples of previous or current foresight projects that could meet needs identified.
- Identify examples of humanitarian organisations and projects utilising methodologies relevant to foresight concepts under consideration (e.g. mapping examples of humanitarians utilising horizon scanning, in the context of the 'technology horizon-scanning coalition' concept).
- Identify resources and networks that support the implementation of the foresight concepts under consideration, to aid consideration of the practical feasibility and resource requirements for implementing them (e.g. identifying existing networks of local workshop facilitators and humanitarian partners that could support the delivery of community engagement-based concepts).

This evidence was then reviewed by the study team, and experts in futures and foresight from RAND Europe's Centre for Futures and Foresight Studies (CFFS) identified futures and foresight methodologies that could be used to address the humanitarian technology foresight initiative opportunities surfaced through the research. Methodologies considered spanned those utilised in previous relevant CFFS projects,[39] including scenario planning, visioning, horizon scanning and participatory futures, as well as others identified by desk research, such as narrative change and research approaches.[40]

The study team then considered these methodologies to develop three concepts for technology foresight initiatives for the humanitarian sector, which were iterated and further developed through ongoing consultation with UKHIH. These consultations considered alignment between foresight concepts and UKHIH's strategic organisational priorities, as well as their wider potential value to the humanitarian sector. To facilitate these discussions, the study team developed four criteria (also in

39 RAND Europe. 2024a. 'Our Research.' Rand.org. As of 6 August 2024: https://www.rand.org/randeurope/initiatives/futures-and-foresight-studies/research.html

40 Narrative change approaches seek to research and change common narratives (e.g. stories, metaphors and language) relating to thematic issues. See: Narrative Initiative. 2024. 'How we do our work.' As of 6 August 2024: https://narrativeinitiative.org/our-work/

consultation with UKHIH) that reflected a range of implementation considerations.

- **Audiences and objectives:** which stakeholder groups will be the intended users and beneficiaries of initiatives, and the nature of these potential benefits. This includes consideration of typical timelines and time horizons of the initiative.
- **Partnerships:** the potential to involve humanitarian stakeholders in the development of insights and strategic actions, with a particular emphasis on local humanitarian organisations.
- **Integration with current practices:** the potential for the foresight initiative to build upon, or integrate with, existing humanitarian networks, schools of humanitarian practice, and other research and foresight communities.
- **Ethical sensitivities:** cultural sensitivities and potential ethical issues that should be considered when implementing the foresight initiative, for example, relating to sensitivities of participant engagement or topic areas.

Aligned with good practice considerations highlighted by interviewees, these criteria reflect the central importance of local partnerships and regional equity, the risks of negative ethical externalities when designing and implementing foresight programmes, and the importance of building on existing communities of practice, language and decision-making fora to achieve impact in humanitarian foresight work. For the criteria for 'Partnerships', 'Integration with current practices', and 'Ethical sensitivities', a basic red-amber-green (RAG) rating was used to highlight the extent to which they are relevant implementation considerations:

- High relevance in green (i.e. partnerships are a prominent and important aspect of the concept methodology, the concept is highly integrated with existing practices, and the concept is associated with a high number of ethical considerations);
- Medium relevance in amber; and
- Low relevance in red.

These assessments were informed by the expert judgement of study team members from RAND Europe's CFFS based on their experiences of projects using the methodologies outlined in the concepts, and evidence on current humanitarian practice gathered through stakeholder consultation and desk research.

As a result, the study team developed three foresight concepts[41]:

1. **An emerging technologies translation initiative** to explore how crises-affected populations conceptualise and frame issues relating to emerging technologies. Such considerations aim to ensure technology narratives reflect the interests of these communities;
2. **A technology horizon-scanning coalition** that would aim to identify trends and promising use cases of emerging technologies with promise across the humanitarian sector; and
3. **A visioning toolkit for emerging technologies in crisis recovery** that would seek to develop a toolkit for humanitarian organisations embedding emerging technologies for crisis recovery.

41 Paillé, Pauline, James Besse, Hampton Toole, Chryssa Politi, Shruti Viswanathan, Eunice Namirembe, Jyoti Nayak & Jacob Ohrvik-Stott. 2024. *Opportunities for supporting humanitarians: Technology Foresight Concepts*. Santa Monica, Calif.: RAND Corporation. RR-A3192-4. As of 17 October 2024: www.rand.org/t/RRA3192-4

Each of the three foresight concepts was presented using Voros' foresight process framework, outlined in Figure 4.2 below, to articulate its scope and activities.[42] This framework was selected as it represents an established good-practice framework that is both flexible for use across different contexts and relatively easy to understand for lay audiences.[43]

The framework was used to outline the following for each of the three foresight concepts:

- **Inputs** that include the data sources that will support the foresight initiative research processes, relating both to externally available data in humanitarian literature and activities and data that will be generated through the foresight process;
- **Foresight** that outlines how these inputs will be analysed and utilised using tailored futures and foresight methodologies. While the study team envisages these processes being coordinated by UKHIH (or an appropriate sub-contractor), they will be co-designed and delivered in partnership with wider humanitarian stakeholders;
- **Outputs** that include artefacts to engage audiences with key themes resulting from the analysis of foresight activities. These outputs will be public-facing by default where they are of relevance to the humanitarian sector, with the caveat

Figure 4.2 Overview of the foresight process

Source: Adapted from Voros (2003).

42 Voros, J. 2003. 'A generic foresight process framework.' Foresight 5(3): 10–21. As of 6 August 2024: https://doi.org/10.1108/14636680310698379

43 As humanitarian audiences for foresight initiative concepts may not have a good understanding of futures and foresight theory or practice, this is important to ensure accessibility of project outputs.

that some sensitive details (e.g. where they relate to specific organisations or case studies of harm) may need to be anonymised or omitted; and

- **Strategy** that covers initiatives that could be developed to respond to the issues and provocations within the foresight analysis and outputs. These initiatives could relate to the strategies of UKHIH, participating organisations and the wider humanitarian sector (where outputs relate to policy recommendations and other advocacy).

For the purpose of this exploratory activity and based on discussions with UKHIH, the study team envisaged a nine-month timeframe for the emerging technology translation initiative. This concept was selected for its focus on crises-affected community stakeholders and the opportunity to expose them to a range of emerging technologies. Based on feedback and to help guide future reflections on the implementation of foresight initiatives within the humanitarian sector, the study team paid particular attention to outline elements relating to:

- Outline activities for each of the framework stages;
- Implementation considerations for activities encompassing relevant good practice, scoping decisions, potential partner networks and relevant external resources;
- Estimated resource requirements associated with each activity in terms of monetary cost, estimated time requirement, and required technical capabilities; and
- Additional scaling activities that could also be conducted to broaden the initiative scope and outputs, but are not essential or feasible to deliver within a nine-month delivery window, outlined for each framework stage.

Chapter 5. Reflections on project approach and delivery

Based on the project activities and the timeframe for delivery, the study team identified the following caveats and reflections.

5.1. Reflections

Project activities focused primarily on publicly available and English-language sources. Horizon scanning conducted in Phase 1 focused on English-language sources that were accessible via public databases. Similarly, guidance reviewed as part of the user research (Phase 3) was based on open-source documentation in English. None of the project activities conducted draw on unpublished, internal or restricted documents or guidance developed within humanitarian organisations, including UN agencies and NGOs.

The focus on English-language sources may mean that the research insights and concepts developed exclude thinking from regions where literature is not published in English (e.g. Francophone sub-Saharan Africa) and from unpublished sources. All stakeholder-based activities conducted by the study team (i.e. survey, interview and workshops) were delivered in English, further restricting access to project activities to non-English speakers. As a result, the insights of this project should not be considered reflective of the humanitarian sector at large nor a comprehensive review of existing scholarship on emerging technologies in the humanitarian sector or of existing humanitarian guidance and foresight activities. Conscious of these limitations, and leveraging Athena Infonomics' capacity and knowledge of the sector, the study team sought to include non-Western and LMIC-focused perspectives.

Lower response rates than anticipated from stakeholders throughout project activities. The relatively low levels of engagement from stakeholders over the course of the project presented a limitation to the project activities and findings pertaining to the use of emerging technologies in the humanitarian sector. From this experience, the study team identified the following insights:

- **There appears to be survey fatigue across the humanitarian sector.** This was emphasised during interview conversations with stakeholders as well as during progress meetings held between the study team and UKHIH. Humanitarians appear to be solicited over and over while their day-to-day activities require high levels of capacity.
- **Time constraints may also have affected survey response rates.** The study team kept the survey open for a limited amount of time (approximately two weeks), while filling out the survey took longer than anticipated, as mentioned by respondents.
- **There were limited opportunities to test the survey** with a small pool of humanitarian stakeholders before fully releasing the survey to ensure that it was fit for purpose and could accommodate humanitarians' limited availability. To reach out to survey participants, the study team selected organisations and stakeholders from the initial mapping of humanitarian activities conducted as part of Phase 1. The mapping was still being refined while subsequent project activities occurred due to time constraints to deliver the project.

As a consequence of the sector mapping conducted and the high volume of results identified in the humanitarian organisations dataset (see Section 2.2), the study team had limited opportunities to develop contacts across these organisations to increase their familiarity with the project and increase stakeholder participation.

- **Time constraints limited the possibility to conduct interviews across the three stages of the project and the Phase 2 workshops over an extended period of time** or to reach out to more humanitarian stakeholders. Overall, the study team conducted limited stakeholder engagement activities compared to the potential pool of stakeholders operating within the humanitarian sector.

The value of project outputs remains untested. Due to project constraints (namely the fast pace of research and limited engagement with the humanitarian sector), specific engagements to test the utility and relevance of the technology guidance and the foresight opportunity could not be undertaken. With regards to the technology guidance, this may limit its use by humanitarians as they seek to explore the adoption of emerging technologies. This remark also applies to other project outputs, with an ongoing need to confirm the extent to which the various project outputs resonate with the needs of stakeholders in the humanitarian sector.

The study team operated in an agile manner. Given the various constraints, the study team established weekly project catch-ups to discuss ongoing and future project activities. These meetings also provided an opportunity for individual team members to present any issues they were facing that may affect the delivery of the project. In addition to these regular meetings, the study team organised ad-hoc meetings when useful, for example prior to the ethics workshop in Phase 2 or the final presentation summarising all project activities delivered to UKHIH in April 2024.

The project relied on an exploratory approach. The research and engagement conducted throughout all three project phases was purposefully exploratory and broad in scope, seeking to identify a wide range of technologies and issues rather than focus on a narrower range of areas in greater depth. Delivering at pace as an 'agile' project has limited stakeholder engagement for some research activities (e.g. the low response rates or breadth of engagement mentioned above) and insights should not be considered representative of the humanitarian sector at large. As a result, the concepts and recommendations within this report should be seen as stimuli to provoke wider ongoing discussion and reflection by the sector regarding how humanitarians should respond to emerging technologies in the longer term.

Annex A. Summary of Phase 1 horizon-scanning outputs

This annex presents the results of the horizon-scanning activities conducted during Phase 1, including a list of technology areas and challenges within the humanitarian sector. Table A.1 presents an overview of the humanitarian challenges identified during Phase 1 activities. Table A.2 presents an overview of the consolidated 50 technology areas resulting from Phase 1 activities, as well as exemplar applications of these technologies.

Table A.1 Overview of humanitarian challenges identified through Phase 1 horizon-scanning activities

Challenge	Challenge type	Working definition[44]
Accessing 'hard-to-reach' populations[45]	Systemic	Groups of people who are difficult to access in humanitarian work, often due to geographic, social or political barriers.
Addressing access disputes[46]	Organisational Ethical Legal	Conflicts or disagreements over access to affected populations or areas in need of humanitarian assistance.
Ensuring access to micro-financing[47]	Systemic	The provision of small loans or financial services to individuals or groups who do not have access to traditional banking or credit systems.
Establishing anticipatory and preventative action[48]	Systemic	Proactive and anticipatory measures taken to prevent or mitigate the impact of crises before they occur or escalate.

44 ChatGPT, output from a prompt by the study team, 'Define [challenge] with reference to the humanitarian sector', 15 December 2023. The study team subsequently reviewed and adapted all results in line with the project scope.

45 Office for the Coordination of Humanitarian Affairs (OCHA). 2022. 'Global Humanitarian Overview 2023.' As of 6 August 2024: https://www.unocha.org/publications/report/world/global-humanitarian-overview-2023-enaresfr

46 Office for the Coordination of Humanitarian Affairs (OCHA). 2023. OCHA's Strategic Plan 2023-2026: *Transforming Humanitarian Coordination*. As of 6 August 2024: https://www.unocha.org/publications/report/world/ochas-strategic-plan-2023-2026-transforming-humanitarian-coordination

47 Gatto, Andrea & Elkhan Richard Sadik-Zada. 2022. 'Access to microfinance as a resilience policy to address sustainable development goals: A content analysis.' *Heliyon* 8(10). As of 6 August 2024: https://doi.org/10.1016/j.heliyon.2022.e10860

48 Office for the Coordination of Humanitarian Affairs (OCHA). 2022. 'Global Humanitarian Overview 2023.' As of 6 August 2024: https://www.unocha.org/publications/report/world/global-humanitarian-overview-2023-enaresfr

Challenge	Challenge type	Working definition[44]
Developing anti-racism and decolonisation approach[49]	Systemic Ethical	Efforts to address and redress systemic racism and colonialism in humanitarian funding and practice.
Ensuring bespoke humanitarian assistance[50]	Technical Organisational	Tailoring support to the specific needs and circumstances of the affected population and region, that differs in form from similar previous humanitarian action.
Disruptive climate change impacts[51]	Systemic	Long-term shifts in climate ecosystem dynamics, including temperatures, ecosystem integrity and weather patterns.
Limited collective accountability[52]	Ethical Organisational Legal	The extent to which humanitarian actors fulfil their obligations and responsibilities to their beneficiaries, including victims of humanitarian crises.
Absence of community participation for data collection[53]	Technical Organisational	The effective formation of partnerships with and between local actors to address data gaps and data quality issues.
Limited complex humanitarian negotiations[54]	Systemic	The complexities of achieving consensus across multiple stakeholders to support the delivery of humanitarian assistance, e.g. to enable access to populations in need.
Limited attention to compound risks[55]	Systemic	Contexts where multiple interconnected risks are present.

49 Peach, Kathy, Aleks Berditchevskaia, Issy Gill, Oli Whittington, Eirini Malliaraki & Nasra Hussein. 2021. 'Collective crisis intelligence for frontline humanitarian response.' As of 6 August 2024: https://www.ukhih.org/documents/3/collective_crisis_intelligence_for_frontline_humanitarian_response.pdf

50 RAND Europe interview, December 2023

51 International Federation of the Red Cross and Red Crescent (IFRC). 2020. 'Come Heat or High Water: Tackling the humanitarian impacts of the climate crisis together.' World Disasters Report 2020 Executive Summary. As of 6 August 2024: https://www.ifrc.org/sites/default/files/2021-09/IFRC_WDR_ExecutiveSummary_EN_Web.pdf

52 Holloway, Kerrie & Oliver Lough. 2020. 'Implementing collective accountability to affected populations.' Humanitarian Policy Group: Policy Brief 78. As of 6 August 2024: https://odi.org/en/publications/implementing-collective-accountability-to-affected-populations-ways-forward-in-large-scale-humanitarian-crises/

53 Panic, Branka. 2022. *Can Emerging Technologies Lead a Revival of Conflict Early Warning/Early Action? Lessons from the Field*. Data for Peacebuilding and Prevention. NYU Centre for International Cooperation. As of 6 August 2024: https://cic.nyu.edu/wp-content/uploads/1662/65/can_emerging_technologies_lead_a_revival_of_conflict_early_warningearly_action_lessons_from_the_field-2022_0.pdf

54 Koenig, Leela. 2023. 'Three pillars that characterise humanitarian negotiation'. As of 6 August 2024: https://www.clingendael.org/news/three-pillars-characterise-humanitarian-negotiation

55 Panic, Branka. 2022. *Can Emerging Technologies Lead a Revival of Conflict Early Warning/Early Action? Lessons from the Field*. Data for Peacebuilding and Prevention. NYU Centre for International Cooperation. As of 6 August 2024: https://cic.nyu.edu/wp-content/uploads/1662/65/can_emerging_technologies_lead_a_revival_of_conflict_early_warningearly_action_lessons_from_the_field-2022_0.pdf

Challenge	Challenge type	Working definition[44]
Increased cost of poverty[56]	Systemic	An economic effect whereby low-income communities (including refugees) may have to pay more for goods and services due to scarcity and high demand competition.
Limited data accuracy[57]	Technical	The degree to which datasets reflect the reality they intend to represent.
Scarce data capacity and skills[58]	Organisational Systemic	The capacity of humanitarian organisations and their employees and volunteers to collect, manage, analyse and use data in their work.
Limited consideration for data ethics[59]	Technical Ethical	The degree to which ethical concerns in how data is gathered, used and safe-guarded are considered when gathering or using data.
Limited data privacy and security[60]	Technical Legal	The degree to which actors can control or restrict how data relating to them is collected and used.
Absence of data quality[61]	Technical	The degree to which the characteristics of data allow it to fulfil its intended purpose.

56 World Food Programme (WFP) Innovation Accelerator. 2024. 'Rapid Response Connectivity Carrier (R2C2): Using drones for humanitarian emergency response.' Innovation Accelerator. As of 6 August 2024: https://innovation.wfp.org/project/r2c2

57 Inter-Agency Standing Committee (IASC). 2021. 'Data Responsibility in Humanitarian Action, Operational Guidance: Results Group 1 on Operational Response.' As of 6 August 2024: https://interagencystandingcommittee.org/sites/default/files/migrated/2021-02/IASC%20Operational%20Guidance%20on%20Data%20Responsibility%20in%20Humanitarian%20Action-%20February%202021.pdf

58 Office for the Coordination of Humanitarian Affairs (OCHA). 2021. 'From digital promise to frontline practice: new and emerging technologies in humanitarian action.' As of 6 August 2024: https://reliefweb.int/report/world/digital-promise-frontline-practice-new-and-emerging-technologies-humanitarian-action

59 Panic, Branka. 2022. *Can Emerging Technologies Lead a Revival of Conflict Early Warning/Early Action? Lessons from the Field*. Data for Peacebuilding and Prevention. NYU Centre for International Cooperation. As of 6 August 2024: https://cic.nyu.edu/wp-content/uploads/1662/65/can_emerging_technologies_lead_a_revival_of_conflict_early_warningearly_action_lessons_from_the_field-2022_0.pdf

60 Inter-Agency Standing Committee (IASC). 2021. 'Data Responsibility in Humanitarian Action, Operational Guidance: Results Group 1 on Operational Response.' As of 6 August 2024: https://interagencystandingcommittee.org/sites/default/files/migrated/2021-02/IASC%20Operational%20Guidance%20on%20Data%20Responsibility%20in%20Humanitarian%20Action-%20February%202021.pdf

61 Inter-Agency Standing Committee (IASC). 2021. 'Data Responsibility in Humanitarian Action, Operational Guidance: Results Group 1 on Operational Response.' As of 6 August 2024: https://interagencystandingcommittee.org/sites/default/files/migrated/2021-02/IASC%20Operational%20Guidance%20on%20Data%20Responsibility%20in%20Humanitarian%20Action-%20February%202021.pdf

Challenge	Challenge type	Working definition[44]
Limited data sovereignty[62]	Ethical Organisational	The degree to which institutions and communities have agency over data produced within their borders.
Lack of data/information integrity[63]	Technical	The accuracy, completeness and quality of data as it is maintained over time and across formats.
Absence of decentralisation and localisation[64]	Organisational Ethical	The extent to which resources, responsibilities and agency are given to local and grass-roots organisations for humanitarian response.
Unmet demand needs[65]	Organisational	Generation of demand for humanitarian goods and services among potential users.
Use of digital extractivism[66]	Technical Ethical	The practice of using digital humanitarian technologies as a means to extract data from data subjects in crisis-affected areas, often to advance economic interests.
Limited energy availability[67]	Systemic	The degree to which energy is available to fulfil humanitarian needs.
Increase of extreme poverty[68]	Systemic	Extreme financial difficulties, defined by the UN as surviving on less than $2.15 per person per day in 2017 purchasing power parity.

62 Dowdeswell, Tracey. 2023. 'Data Sovereignty & Forensic Investigative Genetic Genealogy (FIGG): A Path Forward For Humanitarian & Mass Graves Investigations.' *International Journal of Forensic Sciences* 8(2). As of 6 August 2024: https://ssrn.com/abstract=4463078

63 Inter-Agency Standing Committee (IASC). 2021. 'Data Responsibility in Humanitarian Action, Operational Guidance: Results Group 1 on Operational Response.' As of 6 August 2024: https://interagencystandingcommittee.org/sites/default/files/migrated/2021-02/IASC%20Operational%20Guidance%20on%20Data%20Responsibility%20in%20Humanitarian%20Action-%20February%202021.pdf

64 Peach, Kathy, Aleks Berditchevskaia, Issy Gill, Oli Whittington, Eirini Malliaraki & Nasra Hussein. 2021. 'Collective crisis intelligence for frontline humanitarian response.' As of 6 August 2024: https://www.ukhih.org/documents/3/collective_crisis_intelligence_for_frontline_humanitarian_response.pdf

65 Elrha. 2022. 'How to Scale: Tactics to Enable the Adoption of Humanitarian Innovations.' Scaling Series. As of 6 August 2024: https://www.elrha.org/wp-content/uploads/2022/09/ELRHA_SCALING-SERIES_ADOPTION-OF-HUMANITARIAN-INNOVATIONS.pdf

66 Sandvik, Kristin Bergtora. 2023. *Humanitarian Extractivism: The Digital Transformation of Aid*. Manchester: Manchester University Press.

67 Ndahimana, Epa, Joelle Hangi & Sarah Rosenberg-Jansen. 2023. *Humanitarian Energy Outlook*. GPA, UNITAR. As of 6 August 2024: https://www.humanitarianenergy.org/assets/resources/HEO_2023.pdf

68 Office for the Coordination of Humanitarian Affairs (OCHA).2022. 'Global Humanitarian Overview 2023.' As of 6 August 2024: https://www.unocha.org/publications/report/world/global-humanitarian-overview-2023-enaresfr

Challenge	Challenge type	Working definition[44]
Limited field functionality[69]	Technical	The development of technologies – for example through scaling or integration – so that they are more effective on the ground in humanitarian field contexts (as opposed to only functioning in systems hosted outside of these contexts).
Functional identity issues[70]	Technical Organisational	Issues relating identity as established within a functional ID system, or an ID system designed to provide identification for a range of practical purposes.
Increase of governance gaps[71]	Legal Systemic	Governance gaps in humanitarian work refer to the lack of effective governance structures in crisis-affected areas, which can lead to a breakdown in the delivery of humanitarian aid and services or result in harm.
Limited human/ community-centred design[72]	Technical Ethical	The process of involving publics and affected populations in the design and implementation of humanitarian interventions.
Limited use of humanitarian forensic action[73]	Technical Organisational	The application of forensic science – the application of scientific methods and techniques to matters under investigation by a court of law – to humanitarian activities.
Increase of humanitarian funding gaps[74]	Systemic	Shortfalls in funding for humanitarian programmes and initiatives.

69 Scientific Foresight Unit (STOA). 2019. 'Technological innovation for humanitarian aid and assistance.' European Parliament Research Service (EPRS) Study, Panel for the Future of Science and Technology. PE634.411. As of 6 August 2024: https://www.europarl.europa.eu/RegData/etudes/STUD/2019/634411/EPRS_STU(2019)634411_EN.pdf

70 International Federation of the Red Cross and Red Crescent (IFRC). 2021. 'Digital identity: An Analysis for the Humanitarian Sector.' As of 6 August 2024: https://www.ifrc.org/sites/default/files/2021-12/Digital-Identity%E2%80%93An-Analysis-for-the-Humanitarian-Sector-Final.pdf

71 United Nations Development Programme (UNDP). 2016. *Local Governance in Fragile and Conflict-affected settings: Building a Resilient Foundation for Peace and Development*. A UNDP how-to guide. As of 6 August 2024: https://www.undp.org/sites/g/files/zskgke326/files/publications/Guide_Local_Governance_in_Fragile_and_Conflict_Settings.pdf

72 United Nations Development Programme (UNDP). 2016. *Local Governance in Fragile and Conflict-affected settings: Building a Resilient Foundation for Peace and Development*. A UNDP how-to guide. As of 6 August 2024: https://www.undp.org/sites/g/files/zskgke326/files/publications/Guide_Local_Governance_in_Fragile_and_Conflict_Settings.pdf

73 Dowdeswell, Tracey. 2023. 'Data Sovereignty & Forensic Investigative Genetic Genealogy (FIGG): A Path Forward For Humanitarian & Mass Graves Investigations.' *International Journal of Forensic Sciences* 8(2). As of 6 August 2024: https://ssrn.com/abstract=4463078

74 Peach, Kathy, Aleks Berditchevskaia, Issy Gill, Oli Whittington, Eirini Malliaraki & Nasra Hussein. 2021. 'Collective crisis intelligence for frontline humanitarian response.' As of 6 August 2024: https://www.ukhih.org/documents/3/collective_crisis_intelligence_for_frontline_humanitarian_response.pdf

Challenge	Challenge type	Working definition[44]
Decreasing humanitarian worker security[75]	Organisational	The degree to which measures and protocols to ensure the safety and security of humanitarian workers are put in place, particularly in the field.
Identity verification and management issues[76]	Technical Organisational	The process of verifying the identity (or specific identity characteristics) of an individual or entity, often through the use of trusted documents or biometric data.
Absence of consistent impact measurement[77]	Organisational	The ability of humanitarian actors to assess impacts of humanitarian aid with respects to its effects.
Lack of informed consent[78]	Technical Ethical	The degree to which individuals can provide informed agreement to the use of their personal data.
Limited infrastructure resilience[79]	Systemic	The degree to which humanitarian infrastructure's essential structures and functions are maintained when exposed to hazards.
Limited integration and coordination of humanitarian action[80]	Technical Organisational	The process of bringing together different sectors and actors involved in humanitarian response to work together. Coordination is the process of managing and facilitating the interactions between these actors and sectors.

75 Stoddard, Abby. 2024. 'Running in Place: Security risk management in humanitarian operations.' Humanitarian Outcomes. As of 6 August 2024: https://humanitarianoutcomes.org/publications/running-place-security-risk-management-humanitarian-operations

76 International Federation of the Red Cross and Red Crescent (IFRC). 2021. 'Digital identity: An Analysis for the Humanitarian Sector.' As of 6 August 2024: https://www.ifrc.org/sites/default/files/2021-12/Digital-Identity%E2%80%93An-Analysis-for-the-Humanitarian-Sector-Final.pdf

77 Office for the Coordination of Humanitarian Affairs (OCHA). 2021. 'From digital promise to frontline practice: new and emerging technologies in humanitarian action.' As of 6 August 2024: https://reliefweb.int/report/world/digital-promise-frontline-practice-new-and-emerging-technologies-humanitarian-action

78 International Federation of the Red Cross and Red Crescent (IFRC). 2021. 'Digital identity: An Analysis for the Humanitarian Sector.' As of 6 August 2024: https://www.ifrc.org/sites/default/files/2021-12/Digital-Identity%E2%80%93An-Analysis-for-the-Humanitarian-Sector-Final.pdf

79 United Nations Office for Disaster Risk Reduction (UNDRR). 2023. *Handbook for implementing the principles for resilient infrastructure*. As of 6 August 2024: https://reliefweb.int/report/world/handbook-implementing-principles-resilient-infrastructure

80 United Nations High Commissioner for Refugees (UNHCR). 2024. 'International Coordination Architecture.' As of 6 August 2024: https://emergency.unhcr.org/coordination-and-communication/interagency/international-coordination-architecture

Challenge	Challenge type	Working definition[44]
Limited interoperability[81]	Technical	The ability of organisations and technologies to interact with each other across data, systems and processes to achieve common goals and functions. It involves the sharing of information and knowledge through business processes, by means of the exchange of data between ICT systems.
Lack of transparency[82]	Organisational	The openness of humanitarian organisations about their operations and funding streams to stakeholders outside of their organisation.
Language barriers and translation[83]	Organisational	The extent to which multi-lingual humanitarian workers and people in crisis-hit areas are effectively able to communicate with each other, preserving the meaning, tone and intent of their original communication.
Increased lean and in-time distribution[84]	Technical	The use of efficient and streamlined logistics systems to deliver humanitarian aid and assistance quickly and effectively.
Limited private–public partnerships[85]	Organisational	Partnerships – or lack thereof – between private-sector companies and governmental and public-sector organisations to address humanitarian challenges.
Linear projection fallacy[86]	Organisational Technical	The erroneous assumption that future change will be an extension of past historic data and trends.
Limited access to new and emerging tech[87]	Technical	The degree to which humanitarian actors are reliant on legacy systems and non-state of the art technologies, e.g. where access to novel technologies is limited.

81 Office for the Coordination of Humanitarian Affairs (OCHA). 2021. 'From digital promise to frontline practice: new and emerging technologies in humanitarian action.' As of 6 August 2024: https://reliefweb.int/report/world/digital-promise-frontline-practice-new-and-emerging-technologies-humanitarian-action

82 Inter-Agency Standing Committee (IASC). n.d. 'Greater Transparency.' As of 6 August 2024: https://interagencystandingcommittee.org/greater-transparency

83 Humanitarian Innovation Fund (HIF). 2015. 'Language: A Critical Issue in Humanitarian Response.' As of 6 August 2024: https://www.elrha.org/wp-content/uploads/2015/01/HIF-Translators-Without-Borders-Insert-Doc..pdf

84 World Food Programme (WFP) Innovation Accelerator. 2024. 'Rapid Response Connectivity Carrier (R2C2): Using drones for humanitarian emergency response.' Innovation Accelerator. As of 6 August 2024: https://innovation.wfp.org/project/r2c2

85 Office for the Coordination of Humanitarian Affairs (OCHA). 2020. 'Engagement with the private sector.' As of 6 August 2024: https://www.unocha.org/engagement-private-sector

86 Milojević, Ivana. 2021. 'Futures Fallacies: What They Are and What We Can Do About Them'. *Journal of Future Studies*, 25(4): 1-16. As of 6 August 2024: https://jfsdigital.org/wp-content/uploads/2021/07/01-Milojevic-FuturesFallacies-ED6-Layout.pdf

87 Office for the Coordination of Humanitarian Affairs (OCHA). 2021. 'From digital promise to frontline practice: new and emerging technologies in humanitarian action.' As of 6 August 2024: https://reliefweb.int/report/world/digital-promise-frontline-practice-new-and-emerging-technologies-humanitarian-action

Challenge	Challenge type	Working definition[44]
Limited mobilisation of non-traditional actors[88]	Organisational	Efforts to engage a broader range of stakeholders in humanitarian work relative to those who have historically participated, including local communities, civil society organisations and private-sector entities.
Widening north–south divide[89]	Systemic Ethical	The economic and social disparities between the developed countries of the Northern Hemisphere and the developing countries of the Southern Hemisphere.
Physical infrastructure vulnerability[90]	Systemic	The susceptibility of humanitarian infrastructure and resources to risks that could result in material damage.
Power asymmetries[91]	Organisational Ethical	Power asymmetries are unequal power relations between different actors in humanitarian work, such as between aid providers and recipients, or between different organisations or governments involved in humanitarian response.
Siloed practices[92]	Organisational Systemic	The extent to which there is a lack of knowledge sharing and practical collaboration between humanitarian actors.
Widespread private-sector reliance[93]	Ethical Organisational	The degree to which government and public-sector bodies are reliant on private-sector services and capabilities to deliver their humanitarian activities and responsibilities.
Protracted conflicts[94]	Systemic	Extended conflicts that are characterised by intractability and longevity.

88 Peach, Kathy, Aleks Berditchevskaia, Issy Gill, Oli Whittington, Eirini Malliaraki & Nasra Hussein. 2021. 'Collective crisis intelligence for frontline humanitarian response.' As of 6 August 2024: https://www.ukhih.org/documents/3/collective_crisis_intelligence_for_frontline_humanitarian_response.pdf

89 Gulrajani, Nilima. 2019. 'Moving beyond the North-South impasse in global development: three reasons for optimism.' Overseas Development Institute (ODI). As of 6 August 2024: https://odi.org/en/insights/moving-beyond-the-north-south-impasse-in-global-development-three-reasons-for-optimism/

90 United Nations Office for Disaster Risk Reduction (UNDRR). 2023. *Handbook for implementing the principles for resilient infrastructure*. As of 6 August 2024: https://reliefweb.int/report/world/handbook-implementing-principles-resilient-infrastructure

91 Dahl, Martine T. 2022. 'Power Asymmetries in Humanitarian Aid: A Discourse Analysis of Power Hierarchies between European Citizen Aid Groups and Non-Western People on the Move.' Bachelors thesis, Malmö University. As of 6 August 2024: https://www.diva-portal.org/smash/get/diva2:1694698/FULLTEXT02

92 Viswanathan, Vijayalakshmi. 2023. 'Learning to be more "locally led"? Current practice and evidence gaps in the international humanitarian system.' ODI/ALNAP. As of 6 August 2024: https://reliefweb.int/report/world/learning-be-more-locally-led-current-practice-and-evidence-gaps-international-humanitarian-sector

93 Office for the Coordination of Humanitarian Affairs (OCHA). 2020. 'Engagement with the private sector.' As of 6 August 2024: https://www.unocha.org/engagement-private-sector

94 Peach, Kathy, Aleks Berditchevskaia, Issy Gill, Oli Whittington, Eirini Malliaraki & Nasra Hussein. 2021. 'Collective crisis intelligence for frontline humanitarian response.' As of 6 August 2024: https://www.ukhih.org/documents/3/collective_crisis_intelligence_for_frontline_humanitarian_response.pdf

Challenge	Challenge type	Working definition[44]
Sensitivity of public risk perceptions[95]	Systemic	Public views on the likelihood and severity of different types of risks, their beliefs about the causes and consequences of these risks, and their attitudes towards different types of interventions and responses, independent of the true nature of these risks.
Resource prioritisation towards urgent short-term crises[96]	Organisational	A tendency for resources, such as funding, personnel and equipment, to be allocated to the most urgent short-term needs at the expense of longer-term humanitarian crises.
Limited risk-sharing among humanitarian stakeholders[97]	Legal Organisational	The degree to which risks associated with humanitarian interventions are shared among different stakeholders such that individual stakeholders are not burdened with unacceptable risks.
Sexual exploitation and abuse[98]	Organisational Systemic Ethical	Risks of actual or attempted abuse of someone's position of vulnerability to obtain sexual favours. Sexual abuse means the actual or threatened physical intrusion of a sexual nature, whether by force or under unequal or coercive conditions.
Shrinking civic space[99]	Systemic	The decline or removal of opportunities and resources available to civil society to affect the changes they work towards.

95 Reser, Joseph P., Graham L. Bradley, A. Ian Glendon, Michelle C. Ellul & Rochelle Callaghan. 2012. 'Public risk perceptions, understandings, and responses to climate change and natural disasters in Australia, 2010 and 2011.' National Climate Change Adaptation Research Facility, Gold Coast. As of 6 August 2024: https://core.ac.uk/download/pdf/143882514.pdf

96 Protection Cluster & UNHCR. 2022. 'Protecting & prioritising people with specific needs in the Ukrainian humanitarian response' As of 6 August 2024: https://reliefweb.int/report/ukraine/protecting-prioritising-people-specific-needs-ukrainian-humanitarian-response-may-2022-enuk

97 Viswanathan, Vijayalakshmi. 2023. 'Learning to be more "locally led"? Current practice and evidence gaps in the international humanitarian system.' ODI/ALNAP. As of 6 August 2024: https://reliefweb.int/report/world/learning-be-more-locally-led-current-practice-and-evidence-gaps-international-humanitarian-sector

98 Office for the Coordination of Humanitarian Affairs (OCHA).2022. 'Global Humanitarian Overview 2023.' As of 6 August 2024: https://www.unocha.org/publications/report/world/global-humanitarian-overview-2023-enaresfr

99 Viswanathan, Vijayalakshmi. 2023. 'Learning to be more "locally led"? Current practice and evidence gaps in the international humanitarian system.' ODI/ALNAP. As of 6 August 2024: https://reliefweb.int/report/world/learning-be-more-locally-led-current-practice-and-evidence-gaps-international-humanitarian-sector

Challenge	Challenge type	Working definition[44]
Sociotechnical imaginaries[100]	Technical	Collectively held, organisationally stabilised and publicly performed visions of desirable futures, animated by shared understandings of forms of social order attainable through advances in science and technology. In a humanitarian context this refers to narratives and visions of how technology could support the humanitarian sector – which may or may not be erroneous.
Widespread surveillance[101]	Technical Ethical Legal	The focused and systematic attention to personal details for the purposes of influence, management, protection or direction of the surveilled by the watcher.
Limited technology scaling[102]	Organisational Technical	Challenges associated with the expansion of humanitarian interventions and technologies to a larger user base or geographic area.
Limited technological literacy[103]	Technical Organisational	The ability of individuals to understand and use technologies effectively.
Technology cooperatives[104]	Technical Organisational	The establishment of technology platforms and services whose assets and value (economic or otherwise) are primarily owned by the users.
Techno-solutionism[105]	Technical Ethical	The tendency to rely on technology to solve complex social problems, regardless of its efficacy.

100 Schlapfer, Isabelle. 2021. 'Humanitarian Technologies as Sociotechnical Imaginaries. How Multi-National Companies Impact on the Idea of Humanitarian Action Through Technologies.' As of 6 August 2024: https://research.manchester.ac.uk/en/studentTheses/humanitarian-technologies-as-sociotechnical-imaginaries-how-multi

101 International Federation of the Red Cross and Red Crescent (IFRC). 2017. 'Community-Based Surveillance: guiding principles.' As of 6 August 2024: https://www.ifrc.org/sites/default/files/CommunityBasedSurveillance_Global-LR.pdf

102 Elrha. 2022. 'How to Scale: Tactics to Enable the Adoption of Humanitarian Innovations.' Scaling Series. As of 6 August 2024: https://www.elrha.org/wp-content/uploads/2022/09/ELRHA_SCALING-SERIES_ADOPTION-OF-HUMANITARIAN-INNOVATIONS.pdf

103 Office for the Coordination of Humanitarian Affairs (OCHA). 2021. 'From digital promise to frontline practice: new and emerging technologies in humanitarian action.' As of 6 August 2024: https://reliefweb.int/report/world/digital-promise-frontline-practice-new-and-emerging-technologies-humanitarian-action

104 Dev.to. 2023. 'What is a Tech Cooperative – A Short Introduction.' As of 6 August 2024: https://dev.to/emotionaldaffodil/what-is-a-tech-cooperative-a-short-introduction-m3k

105 Peach, Kathy, Aleks Berditchevskaia, Issy Gill, Oli Whittington, Eirini Malliaraki & Nasra Hussein. 2021. 'Collective crisis intelligence for frontline humanitarian response.' As of 6 August 2024: https://www.ukhih.org/documents/3/collective_crisis_intelligence_for_frontline_humanitarian_response.pdf

Challenge	Challenge type	Working definition[44]
Persistent top-down donor approaches[106]	Systemic Organisational	A model of aid delivery in which decisions about the allocation and distribution of resources are made by donors or aid organisations at the top of a hierarchy, rather than by the affected communities themselves.
Traceability issues of humanitarian goods and services[107]	Organisational Institutional	The extent to which the movement of goods, services and funds throughout the supply chain, from the point of origin to the point of consumption or distribution, can be tracked by different stakeholders.
Fragile water security and abundance[108]	Technical	The availability, or lack thereof, of water to communities and humanitarian organisations.

Table A.2 Overview of longlist of technology areas identified through horizon-scanning activities

Technology area	Definition[109]	Exemplar devices and application
Advanced food production[110]	The use of technologies and practices to increase the efficiency, productivity and sustainability of food production. This includes the use of precision agriculture, biotechnology, data analytics and other cutting-edge methods to optimise the entire food supply chain.	Additive food manufacturing Novel protein sources Non-thermal food processing technologies Biodegradable and edible packaging Advanced aeroponics systems

106 Bloom, Louise & Dr Alexander Betts. 2013. 'The two worlds of humanitarian innovation.' *Refugee Studies Centre Working Paper Series* 94. As of 6 August 2024: https://www.unhcr.org/innovation/wp-content/uploads/2017/10/wp94-two-worlds-humanitarian-innovation-2013.pdf

107 United States Agency for International Development (USAID). 2020. 'Improving the tracking and traceability of U.S. Food Aid: A Feasibility Study.' As of 6 August 2024: https://pdf.usaid.gov/pdf_docs/PA00X57V.pdf

108 Solidarités International. 2022. 'Water Security: Issues, Challenges and Solutions.' As of 6 August 2024: https://www.solidarites.org/wp-content/uploads/2022/02/2022-water-barometer-solidarites-international.pdf

109 ChatGPT output from a prompt by the research team, 'Define [technology area] with reference to the humanitarian sector', 15 December 2023. The study team subsequently reviewed and adapted all results in line with the project scope.

110 Short, Samuel, Bernhard Strauss & Pantea Lotfian. 2021. 'Emerging technologies that will impact on the UK Food System, Rapid Evidence Assessment.' Food Standards Agency. As of 6 August 2024: https://www.food.gov.uk/sites/default/files/media/document/emerging-technologies-report.pdf

Technology area	Definition[109]	Exemplar devices and application
Advanced infrastructure component manufacturing[111]	Production systems for high-quality components for infrastructure projects. This includes the use of advanced materials, such as composites and alloys, as well as the use of automation and robotics to improve efficiency and precision in manufacturing.	3D printing for field manufacturing Printable electronics and hardware 4D printing Multi-material 3D printing Underbody shield composites 3D printing of inorganic nanomaterials
Advanced shelter construction and defence[112]	Systems to design and build high-quality shelters that can withstand natural disasters and other threats. This includes the use of advanced materials, such as reinforced concrete and steel, as well as the use of sensors and other monitoring devices to improve safety and security.	3D printing for shelters Lightweight portable modular shelters Flood refugee shelters Post-disaster shelter evaluation models Automatic fire extinguishing devices
Advanced water treatment[113]	Using technologies and techniques to purify and treat water for various purposes, such as drinking, irrigation and industrial use. This includes the use of advanced filtration systems, chemical treatments and other methods to remove contaminants and improve water quality.	Desalination nanotechnologies In-pipe drinking water chlorination Mobile water purifiers

111 Scientific Foresight Unit (STOA). 2019. 'Technological innovation for humanitarian aid and assistance.' European Parliament Research Service (EPRS) Study, Panel for the Future of Science and Technology. PE634.411. As of 6 August 2024: https://www.europarl.europa.eu/RegData/etudes/STUD/2019/634411/EPRS_STU(2019)634411_EN.pdf

112 Scientific Foresight Unit (STOA). 2019. 'Technological innovation for humanitarian aid and assistance.' European Parliament Research Service (EPRS) Study, Panel for the Future of Science and Technology. PE634.411. As of 6 August 2024: https://www.europarl.europa.eu/RegData/etudes/STUD/2019/634411/EPRS_STU(2019)634411_EN.pdf

113 Solidarités International. 2022. 'Water Security: Issues, Challenges and Solutions.' As of 6 August 2024: https://www.solidarites.org/wp-content/uploads/2022/02/2022-water-barometer-solidarites-international.pdf; Oksen, Peter & Lise Favre. 2020. 'Innovative technology in the Water, Sanitation and Hygiene (WASH) sector.' Global Challenges in Focus, World Intellectual Property Organization. As of 6 August 2024: https://www.wipo.int/edocs/pubdocs/en/wipo_pub_gc_20_1.pdf

Technology area	Definition[109]	Exemplar devices and application
Advanced wireless communication systems[114]	Using technologies and techniques to design and build high-speed, reliable wireless networks for various applications, such as mobile communication, internet of things (IoT) and smart cities. This includes the use of advanced antennas, signal processing algorithms and other methods to improve network coverage, capacity and efficiency.	Remotely reconfigurable radio systems
Advanced wound care[115]	The use of technologies, techniques and products to promote the healing of chronic or complex wounds. This includes the use of specialised dressings, such as hydrogels and foams, as well as the use of negative pressure wound therapy, hyperbaric oxygen therapy and other advanced treatments to promote tissue regeneration and prevent infection.	Nanotherapeutics Bioengineered skin grafts Stem-cell therapy Manual pressure pump for wound treatment Maggot-assisted wound therapy
Agile cargo storage and delivery[116]	The optimised storage and transportation of goods and products, including the use of advanced logistics software (e.g. warehouse management systems and transportation management systems) or novel materials and deployment mechanisms to improve efficiency and speed in cargo handling.	Parachute landing platforms Emergency evacuation containers

114 Dali Syst Ltd. 2023. 'Remotely reconfigurable distributed antenna system and methods.' US20230319802A1. analytics.patsnap.com. As of 6 August 2024: https://analytics.patsnap.com/patent-view/abst?patentId=6ceef963-377d-4b69-9cc6-7bdfd9824105; Sudan, Sanjna & Anaswara Kovithal. 2023. 'Sixteen Technology-Driven Innovations Tackle Emergency and Humanitarian Challenges'. As of 6 August 2024: https://wfpinnovation.medium.com/sixteen-technology-driven-innovations-tackle-emergency-and-humanitarian-challenges-facc76a76919

115 Kolimi, Praveen, Sagar Narala, Dinesh Nyavanandi, Ahmed A. A. Youssef & Narendar Dudhipala. 2022. 'Innovative Treatment Strategies to Accelerate Wound Healing: Trajectory and Recent Advancements.' *Cells* 11(15): 2439. As of 6 August 2024: https://doi.org/10.3390/cells11152439

116 Scientific Foresight Unit (STOA). 2019. 'Technological innovation for humanitarian aid and assistance.' European Parliament Research Service (EPRS) Study, Panel for the Future of Science and Technology. PE634.411. As of 6 August 2024: https://www.europarl.europa.eu/RegData/etudes/STUD/2019/634411/EPRS_STU(2019)634411_EN.pdf

Technology area	Definition[109]	Exemplar devices and application
Automated disaster early-warning systems[117]	Using technologies and techniques to detect and alert people about potential natural disasters (e.g. earthquakes, tsunamis, hurricanes, floods), typically using sensors, satellite imagery and other monitoring devices to detect changes in environmental conditions, as well as the use of automated algorithms and machine learning to analyse data and issue warnings in real-time. Automated disaster early-warning systems are designed to improve the speed and accuracy of disaster response, and to help minimise the impact of disasters on people and communities.	Flood early-warning systems (TAHMO) Automated mobile alert systems Adaptive response messaging Landslide prediction and warning system
Biohazard treatments[118]	The systems and techniques used to decontaminate and disinfect areas that have been exposed to hazardous biological materials (e.g. viruses, bacteria and other pathogens), including the use of specialised cleaning agents, such as bleach and hydrogen peroxide, as well as the use of personal protective equipment, such as gloves, masks and gowns, to prevent exposure to hazardous materials. Biohazard treatments are often used in healthcare facilities, laboratories and other settings where the risk of exposure to infectious diseases is high.	Multi-antibody therapeutics Bioweapon vaccines Plasma air sterilisation device
Biometrics and identity technologies[119]	Technologies to identify and authenticate individuals based on their unique physical or behavioural characteristics, including the use of biometric data (e.g. fingerprints, facial recognition and iris scans), as well as the use of behavioural biometrics (e.g. keystroke dynamics and voice recognition) to verify a person's identity. Biometrics and identity technologies are used in a variety of applications, such as access control, border security and financial transactions, to improve security and prevent fraud.	Digital identity cards Iris scanning Fingerprint scanning Blood donor databases Wearable biometric health monitoring

117 Fontes de Meira, Luciana & Omar Bello. 2020. 'The use of technology and innovative approaches in disaster and risk management: a characterization of Caribbean countries' experiences.' *Studies and Perspectives – ECLAC Subregional Headquarters for the Caribbean* 93. As of 6 August 2024: https://repositorio.cepal.org/server/api/core/bitstreams/d1f94a03-ab00-4b25-9b3d-98239b5327c1/content

118 Short, Samuel, Bernhard Strauss & Pantea Lotfian. 2021. 'Emerging technologies that will impact on the UK Food System, Rapid Evidence Assessment.' Food Standards Agency. As of 6 August 2024: https://www.food.gov.uk/sites/default/files/media/document/emerging-technologies-report.pdf

119 Kapoor, Charmie, Divyanka Kapoor, Nishu Lahoti & Trevor Cobb Storm. 2020. 'Aid Demand Aggregation Using Technology During Disaster Relief.' In *HCI International 2020 – Posters*, edited by C. Stephanidis & M. Antona, 439–448. Springer, Cham. As of 6 August 2024: https://link.springer.com/chapter/10.1007/978-3-030-50732-9_57; Simprints. n.d. 'How it works.' As of 6 August 2024: https://www.simprints.com/solution; Scientific Foresight Unit (STOA). 2019. 'Technological innovation for humanitarian aid and assistance.' European Parliament Research Service (EPRS) Study, Panel for the Future of Science and Technology. PE634.411. As of 6 August 2024: https://www.europarl.europa.eu/RegData/etudes/STUD/2019/634411/EPRS_STU(2019)634411_EN.pdf

Technology area	Definition[109]	Exemplar devices and application
Blockchains and decentralised technologies[120]	Technologies used to create distributed, secure and transparent systems for storing and sharing data and information, including blockchain technology, which uses a decentralised ledger to record transactions and ensure the integrity of data, as well as the use of peer-to-peer networks and other decentralised architectures to enable secure and efficient data sharing. Blockchains and decentralised technologies are used in a variety of applications (e.g. cryptocurrency, supply chain management, voting systems) to improve transparency, security and efficiency.	Blockchain for product distribution Blockchain for payment tracking and distribution Blockchain for food distribution
Blood treatment and delivery[121]	Systems used to collect, process, store and transport blood and blood products for transfusion (e.g. using specialised equipment, such as blood collection bags and refrigeration units, as well as the use of advanced processing techniques, such as leukoreduction and irradiation, to improve the safety and quality of blood products). Blood treatment and delivery also involves the use of logistics and transportation systems to ensure that blood products are delivered to hospitals and other healthcare facilities in a timely and efficient manner.	Blood donor databases Blood conversion enzymes Blood delivery drones
Camp monitoring systems[122]	Systems to monitor and manage refugee camps, detention centres and other temporary settlements, including deploying sensors, cameras and other monitoring devices to track the movement of people and goods, as well as using data analytics and machine learning to identify patterns and trends in camp activities. Camp monitoring systems are designed to improve the safety, security and well-being of people living in temporary settlements, and to help humanitarian organisations and governments respond more effectively to crises and emergencies.	Camp fire alert systems Real-time water supply monitoring Rapid-deployment perimeter monitor

120 Rodríguez-Espíndola, Oscar, Soumyadeb Chowdhury, Ahmad Beltagui & Pavel Albores. 2020. 'The potential of emergent disruptive technologies for humanitarian supply chains: the integration of blockchain, Artificial Intelligence and 3D printing.' *International Journal of Production Research* 58(15): 4610–4630. As of 6 August 2024: https://doi.org/10.1080/00207543.2020.1761565

121 Sodero, Stephanie & Richard Rackham. 2020. 'Blood drones: using utopia as method to imagine future vital mobilities.' *Mobilities* 15(1): 11–24. As of 6 August 2024: https://doi.org/10.1080/17450101.2019.1673034

122 RAND Europe interview, December 2023

Technology area	Definition[109]	Exemplar devices and application
Cyber-threat defence[123]	The methods and techniques used to protect computer systems, networks and data from unauthorised access, theft or damage by cybercriminals and other malicious actors, including the use of firewalls, intrusion detection and prevention systems, and other security technologies to prevent cyber attacks, as well as the use of encryption, access controls and other security measures to protect sensitive data. Cyber-threat defence also involves the use of incident response plans and other strategies to detect and respond to cyber attacks in a timely and effective manner.	Non-disruptive cyber-attack testing services Misinformation response system Image verification software
Dynamic/micro internet access systems[124]	Using technologies and techniques to provide high-speed, reliable internet access in areas where traditional broadband infrastructure is unavailable or insufficient, to create ad-hoc networks that can provide internet access to remote or underserved areas. Dynamic/micro internet access systems are often intended to improve connectivity and bridge digital access inequalities, particularly in rural and developing regions where access to the internet is limited.	Wi-Fi scaling devices Rapid response connectivity carrier Starlink
Edtech and remote learning[125]	Systems and applications to deliver educational content and facilitate learning outside of traditional classroom settings, including deploying online learning platforms (e.g. learning management systems and massive open online courses, or MOOCs), as well as the use of video conferencing, virtual reality and other technologies to enable remote instruction and collaboration. Edtech and remote learning are designed to improve access to education, particularly in areas where traditional educational resources are limited or unavailable, and to provide flexible and personalised learning experiences for students of all ages.	Mobile-enabled education content Virtual training for health workers Digital legal aid

123 Sealr. 2020. 'Snap Truth to Power.' As of 6 August 2024: https://humanitariangrandchallenge.org/innovator/sealr/

124 World Food Programme (WFP) Innovation Accelerator. 2024. 'Rapid Response Connectivity Carrier (R2C2): Using drones for humanitarian emergency response.' Innovation Accelerator. As of 6 August 2024: https://innovation.wfp.org/project/r2c2;
Sudan, Sanjna & Anaswara Kovithal. 2023. 'Sixteen Technology-Driven Innovations Tackle Emergency and Humanitarian Challenges'. As of 6 August 2024: https://wfpinnovation.medium.com/sixteen-technology-driven-innovations-tackle-emergency-and-humanitarian-challenges-facc76a76919

125 Scientific Foresight Unit (STOA). 2019. 'Technological innovation for humanitarian aid and assistance.' European Parliament Research Service (EPRS) Study, Panel for the Future of Science and Technology. PE634.411. As of 6 August 2024: https://www.europarl.europa.eu/RegData/etudes/STUD/2019/634411/EPRS_STU(2019)634411_EN.pdf

Technology area	Definition[109]	Exemplar devices and application
Environmental observation systems[126]	Systems to monitor and study the natural environment (e.g. the atmosphere, oceans, land and ecosystems), including using sensors, satellites and other monitoring devices to collect data on environmental conditions, as well as using data analytics and machine learning to analyse and interpret the data. Environmental observation systems are used in a variety of applications, such as weather forecasting, climate modelling and natural resource management, to improve our understanding of the environment and to inform policy and decision making.	Hydrometeorological tools for disaster risk management High-altitude pseudo-satellites No-code platforms for environmental observations
Food access and cooking tools[127]	The methods and technologies used to improve access to healthy and nutritious food, as well as the tools and equipment used to prepare and cook food. This includes tools to make cooking easier, faster, safer or more efficient.	Automated commodity-dispensing machines Heat-retention cooking bags
Food nanotechnologies[128]	The use of nanoscale materials and processes to improve the quality, safety and nutritional value of food. This includes the use of nanoparticles, nanocapsules and other nanomaterials to enhance food texture, flavour and shelf life, as well as the use of nanosensors and other monitoring devices to improve food safety and traceability.	Nanotechnologies for prevention of microbial contamination Nanotechnologies for smart food packaging
Food testing and preservation[129]	The methods and techniques used to ensure the safety and quality of food products. Food testing involves the analysis of food samples to detect the presence of contaminants, such as pathogens, pesticides and heavy metals, while food preservation involves the use of various methods, such as refrigeration, canning and drying, to extend the shelf life of food products and prevent spoilage.	Post-harvest loss management technologies Rapid micro-nutrient testing Food cleaning testing Novel insecticidal proteins

126 Fontes de Meira, Luciana & Omar Bello. 2020. 'The use of technology and innovative approaches in disaster and risk management: a characterization of Caribbean countries' experiences.' *Studies and Perspectives – ECLAC Subregional Headquarters for the Caribbean* 93. As of 6 August 2024: https://repositorio.cepal.org/server/api/core/bitstreams/d1f94a03-ab00-4b25-9b3d-98239b5327c1/content

127 Short, Samuel, Bernhard Strauss & Pantea Lotfian. 2021. 'Emerging technologies that will impact on the UK Food System, Rapid Evidence Assessment.' Food Standards Agency. As of 6 August 2024: https://www.food.gov.uk/sites/default/files/media/document/emerging-technologies-report.pdf

128 Short, Samuel, Bernhard Strauss & Pantea Lotfian. 2021. 'Emerging technologies that will impact on the UK Food System, Rapid Evidence Assessment.' Food Standards Agency. As of 6 August 2024: https://www.food.gov.uk/sites/default/files/media/document/emerging-technologies-report.pdf

129 Short, Samuel, Bernhard Strauss & Pantea Lotfian. 2021. 'Emerging technologies that will impact on the UK Food System, Rapid Evidence Assessment.' Food Standards Agency. As of 6 August 2024: https://www.food.gov.uk/sites/default/files/media/document/emerging-technologies-report.pdf

Technology area	Definition[109]	Exemplar devices and application
Forensic investigative genealogy[130]	Deploying genetic testing and genealogical research techniques to identify suspects in criminal investigations, including the use of DNA analysis to create genetic profiles of suspects, as well as the use of genealogical databases and other public records to trace family trees and identify potential relatives of suspects. Forensic investigative genealogy is used in a variety of criminal investigations, such as cold cases and unidentified remains, to help law enforcement agencies solve crimes and bring perpetrators to justice.	DNA justice databases
Goods and product tracking[131]	Using technologies and techniques to monitor and track the movement of goods and products throughout the supply chain, from production to delivery (e.g. barcodes, RFID tags and other tracking technologies to identify and track individual items, as well as the use of logistics software and data analytics to optimise supply-chain operations and improve efficiency). Goods and product tracking is used in a variety of industries, such as retail, manufacturing and logistics, to improve inventory management, reduce waste and enhance customer satisfaction.	Food tracing applications
Health pathogen detection and treatment[132]	The methods and techniques used to detect and treat infectious diseases caused by pathogens (e.g. viruses, bacteria and fungi), including the use of diagnostic tests, such as PCR and ELISA, to identify the presence of pathogens in patient samples, as well as the use of antibiotics, antivirals and other medications to treat infections. Health pathogen detection and treatment also involve the use of infection control measures, such as hand hygiene and isolation precautions, to prevent the spread of infectious diseases in healthcare settings.	PCR tests for MRSA viruses Nanomaterials for pathogen detection Antibody alternatives Microfluidic devices for biosensors

130 Dowdeswell, Tracey. 2023. 'Data Sovereignty & Forensic Investigative Genetic Genealogy (FIGG): A Path Forward For Humanitarian & Mass Graves Investigations.' *International Journal of Forensic Sciences* 8(2). As of 6 August 2024: https://ssrn.com/abstract=4463078

131 United States Agency for International Development (USAID). 2020. 'Improving the tracking and traceability of U.S. Food Aid: A Feasibility Study.' As of 6 August 2024: https://pdf.usaid.gov/pdf_docs/PA00X57V.pdf

132 Roy, Sharmili, Fareeha Arshad, Shimaa Eissa, Mohammadali Safavieh, Sanaa G. Alattas, Minhaz Uddin Ahmed ORCID & Mohammed Zourob. 2022. 'Recent developments towards portable point-of-care diagnostic devices for pathogen detection.' *Sensors & Diagnostics* 1: 87–105. As of 6 August 2024: https://pubs.rsc.org/en/content/articlehtml/2022/sd/d1sd00017a

Technology area	Definition[109]	Exemplar devices and application
Humanitarian service aggregation and response coordination[133]	The use of technologies and techniques to coordinate and manage humanitarian aid and response efforts in times of crisis or emergency, including the use of digital platforms and mobile applications to aggregate information on needs and resources, as well as the use of data analytics and machine learning to identify patterns and trends in humanitarian crises. Humanitarian service aggregation and response coordination also involve the use of logistics and transportation systems to deliver aid and supplies to affected areas, as well as the use of communication technologies to coordinate response efforts among humanitarian organisations and government agencies.	Security service aggregators Emergency response coordination platforms Dynamic field operations platform
Logistics and infrastructure optimisation[134]	Using technologies and techniques to improve the efficiency and effectiveness of logistics and infrastructure operations, incorporating data analytics and machine learning to optimise supply-chain operations (e.g. inventory management, transportation and warehousing) as well as advanced modelling and simulation tools to design and optimise infrastructure systems (e.g. transportation networks, energy grids and water systems). These technologies are already applied in diverse industries (e.g. manufacturing, transportation and energy) to reduce costs, improve productivity and enhance sustainability.	Drone charging station optimisation Logistics optimisation platforms Blockchain in Shared Manufacturing (BBSAM) protocol

133 Fontes de Meira, Luciana & Omar Bello. 2020. 'The use of technology and innovative approaches in disaster and risk management: a characterization of Caribbean countries' experiences.' *Studies and Perspectives – ECLAC Subregional Headquarters for the Caribbean* 93. As of 6 August 2024: https://repositorio.cepal.org/server/api/core/bitstreams/d1f94a03-ab00-4b25-9b3d-98239b5327c1/content;
Fan, Chao, Cheng Zhang, Alex Yahja & Ali Mostafavi. 2021. 'Disaster City Digital Twin: A vision for integrating artificial and human intelligence for disaster management.' *International Journal of Information Management* 56. As of 6 August 2024: https://doi.org/10.1016/j.ijinfomgt.2019.102049;
Sudan, Sanjna & Anaswara Kovithal. 2023. 'Sixteen Technology-Driven Innovations Tackle Emergency and Humanitarian Challenges'. As of 6 August 2024: https://wfpinnovation.medium.com/sixteen-technology-driven-innovations-tackle-emergency-and-humanitarian-challenges-facc76a76919

134 Fosso Wamba, Samuel, Maciel M. Queiroz, Samuel Roscoe, Wendy Phillips, Dharm Kapletia & Arash Azadegan. 2021. 'Guest editorial: Emerging technologies in emergency situations.' *International Journal of Operations & Production Management* 41(9): 1405–1416. As of 6 August 2024: https://doi.org/10.1108/IJOPM-09-2021-904

Technology area	Definition[109]	Exemplar devices and application
Medical manufacturing devices[135]	Specialised equipment and machinery used to produce medical devices (e.g. surgical instruments, diagnostic equipment and implantable devices), including the use of advanced manufacturing technologies (e.g. 3D printing, laser cutting, microfabrication) to produce complex and precise medical devices, as well as the use of specialised materials (e.g. biocompatible polymers and metals) to ensure the safety and effectiveness of medical devices. Medical manufacturing devices are used in various healthcare settings (e.g. hospitals, clinics and research laboratories) to support patient care and advance medical research.	Portable micro-factory for pharmaceutical serum
Micro-energy solutions[136]	Systems to provide small-scale, decentralised energy solutions for off-grid and underserved communities, notably deploying renewable energy sources (e.g. solar, wind and hydro power) to generate electricity and using energy storage systems (e.g. batteries and fuel cells) to store and distribute energy. Micro-energy solutions are designed to improve access to reliable and affordable energy, particularly in rural and developing regions where traditional energy infrastructure is limited or unavailable, and to promote sustainable development and reduce greenhouse gas emissions.	Small-scale waste-to-energy convertors Portable battery grid systems (POPO) Solar mini-grids

135 Bureau Diocésain des Oeuvres Médicales. 2021. 'A Portable Micro Factory for Point of Use Production of Pharmaceutical Grade IV Serum.' As of 6 August 2024: https://humanitariangrandchallenge.org/innovator/a-portable-micro-factory-for-point-of-use-production-of-pharmaceutical-grade-iv-serum/

136 Sudan, Sanjna & Anaswara Kovithal. 2023. 'Sixteen Technology-Driven Innovations Tackle Emergency and Humanitarian Challenges'. As of 6 August 2024: https://wfpinnovation.medium.com/sixteen-technology-driven-innovations-tackle-emergency-and-humanitarian-challenges-facc76a76919

Technology area	Definition[109]	Exemplar devices and application
Micro-finance and acute financial support[137]	Small-scale financial services and emergency financial assistance to support individuals and communities in need: while micro-finance involves the provision of small loans, savings accounts and other financial services to low-income individuals and small businesses (particularly in developing regions where traditional banking services are limited or unavailable), acute financial support involves giving emergency financial assistance (e.g. cash transfers or grants) to individuals and communities affected by natural disasters, conflicts or other crises. Micro-finance and acute financial support are designed to promote financial inclusion, reduce poverty and improve resilience in vulnerable populations.	Micro-insurance Micro-credit Post-disaster mobile payments Anticipatory Cash and Voucher Assistance (CVA) platforms (Rumsan)
Migration and human movement monitoring[138]	Technology systems to monitor and track the movement of people across borders and within countries, including biometric data (e.g. fingerprints and facial recognition) to identify and track individuals, as well as using satellite imagery, drones and other monitoring devices to detect and track migration patterns. Migration and human movement monitoring are used in various applications (e.g. border security, refugee management and human-trafficking prevention) to improve the safety and security of people on the move and to inform policy and decision making.	Cloud computing 'Crowd-forming apps'

137 Gatto, Andrea & Elkhan Richard Sadik-Zada. 2022. 'Access to microfinance as a resilience policy to address sustainable development goals: A content analysis.' *Heliyon* 8(10). As of 6 August 2024: https://doi.org/10.1016/j.heliyon.2022.e10860;
Fontes de Meira, Luciana & Omar Bello. 2020. 'The use of technology and innovative approaches in disaster and risk management: a characterization of Caribbean countries' experiences.' *Studies and Perspectives – ECLAC Subregional Headquarters for the Caribbean* 93. As of 6 August 2024: https://repositorio.cepal.org/server/api/core/bitstreams/d1f94a03-ab00-4b25-9b3d-98239b5327c1/content;
Scientific Foresight Unit (STOA). 2019. 'Technological innovation for humanitarian aid and assistance.' European Parliament Research Service (EPRS) Study, Panel for the Future of Science and Technology. PE634.411. As of 6 August 2024: https://www.europarl.europa.eu/RegData/etudes/STUD/2019/634411/EPRS_STU(2019)634411_EN.pdf
Sudan, Sanjna & Anaswara Kovithal. 2023. 'Sixteen Technology-Driven Innovations Tackle Emergency and Humanitarian Challenges'. As of 6 August 2024: https://wfpinnovation.medium.com/sixteen-technology-driven-innovations-tackle-emergency-and-humanitarian-challenges-facc76a76919

138 Nalbandian, Lucia & Nick Dreher. 2022. 'Advanced Digital Technologies in Migration Management: A Review of Emerging Literature.' TMCIS/CERC, *Working Paper* series 2022/11. As of 6 August 2024: https://www.torontomu.ca/content/dam/centre-for-immigration-and-settlement/tmcis/publications/workingpapers/2022_11_Nalbandian_L_Dreher_N_Advanced_Digital_Technologies_in_Migration_Management_A_Review_of_Emerging_Literature.pdf

Technology area	Definition[109]	Exemplar devices and application
Modular transport infrastructure[139]	Pre-fabricated and standardised components to build transport infrastructure (e.g. roads, bridges and tunnels) in a faster, more efficient and cost-effective manner, including the use of modular designs and construction techniques (e.g. precast concrete and steel structures) to reduce construction time and costs as well as the use of digital technologies (e.g. Building Information Modelling, BIM) to optimise the design and construction process. Modular transport infrastructure is used in a variety of applications, such as urban development, transportation networks and disaster response, to improve mobility, connectivity and resilience.	Over-decking systems
Multi-surface vehicles[140]	Vehicles that can operate on multiple surfaces (e.g. land, water and air), including amphibious vehicles, such as hovercraft and airboats, that can travel on both land and water, as well as the use of hybrid vehicles, such as flying cars and hoverbikes, that can travel on both land and air. Multi-surface vehicles are designed to improve mobility and transportation in a variety of settings, such as emergency response, military operations and transportation networks, and to promote innovation and sustainability in the transportation industry.	Hybrid aerial–aquatic robot
Novel data analytics[141]	Systems to analyse and interpret large and complex datasets in new and innovative ways, notably by employing machine learning, artificial intelligence and other advanced analytics tools to identify patterns, trends and insights in data, as well as the use of data visualisation and storytelling techniques to communicate findings and engage stakeholders. Novel data analytics are used in a variety of applications, such as business intelligence, healthcare and social sciences, to inform decision making, improve performance and drive innovation.	Social media analysis Call Detail Records

139 United States (US Army). 2022. 'Over decking systems and methods.' US11214932B2. As of 6 August 2024: https://worldwide.espacenet.com/patent/search/family/078221845/publication/US11214932B2?q=pn%3DUS11214932B2

140 Li, Lei, Wenbo Liu, Bocheng Tian, Peiyu Hu, Wenzhuo Gao, Yuchen Liu, Fuqiang Yang, Youning Duo, Hongru Cai, Yiyuan Zhang, Zhouhao Zhang, Zimo Li & Li Wen. 2023. 'An Aerial–Aquatic Hitchhiking Robot with Remora-Inspired Tactile Sensors and Thrust Vectoring Units'. *Advanced Intelligence Systems*. As of 6 August 2024: https://doi.org/10.1002/aisy.202300381

141 Winowatan, Michelle, Andrew J. Zahuranec, Andrew Young & Stefaan G. Verhulst. 2020. 'Leveraging Telecom Data to Aid Humanitarian Efforts: Lessons Learned from the 2015 Earthquake in Nepal.' GovLab. As of 6 August 2024: https://directus.thegovlab.com/uploads/thegovlab/blog_img_archive/2020/10/Flowminder_NCell-Data-Collab-Case-Study-FINAL.pdf

Technology area	Definition[109]	Exemplar devices and application
Novel energy security and efficiency technologies[142]	Modern systems to improve the security and efficiency of energy systems, including renewable energy sources (e.g. solar, wind and geothermal power) to reduce dependence on fossil fuels and enhance energy security and energy storage systems (e.g. batteries and fuel cells) to store and distribute energy more efficiently. These technologies also include using smart grid technologies, such as advanced metering and demand response systems, to optimise energy use and reduce waste; these technologies are used in a variety of applications, such as transportation, construction and industry, to promote sustainability, reduce greenhouse gas emissions and enhance energy security.	Power failure risk test systems Hydrogen fuel cell flood protection Saturation mitigation in wireless power systems PCM material for Solar-Thermal Energy Conversion
Novel mental health treatments[143]	New and innovative treatments for mental health disorders, for example including novel psychoactive substance discovery, digital therapeutics, precision mental health medicine or brain stimulation techniques.	Psilocybin treatments
Novel waste treatment systems[144]	Systems to treat and manage human, industrial or other waste in new and innovative ways, including advanced recycling technologies, waste-to-energy technologies and smart waste management systems, such as sensor-based waste sorting and collection.	Faecal sludge treatment unit Healthcare waste incinerator Small-scale waste-to-energy convertors Lightweight portable septic tanks Laminate-lined pit latrines

142 Apple Inc. 2022. 'Methods and circuitry for mitigating saturation in wireless power systems.' . IN202214002318A. analytics.patsnap.com. As of 6 August 2024: https://analytics.patsnap.com/patent-view/abst?patentId=b36380cc-a461-4d67-8036-968645bcafad

143 Compass Pathfinder Ltd. 2023. '用賽洛西賓治療抑鬱症和其他各種病症 [Using psilocybin to treat depression and other various conditions].' HK40068440A. analytics.patsnap.com. As of 6 August 2024: https://analytics.patsnap.com/patent-view/abst?patentId=107df488-2aff-408e-b6a0-21e906d8d40e

144 Sudan, Sanjna & Anaswara Kovithal. 2023. 'Sixteen Technology-Driven Innovations Tackle Emergency and Humanitarian Challenges'. As of 6 August 2024: https://wfpinnovation.medium.com/sixteen-technology-driven-innovations-tackle-emergency-and-humanitarian-challenges-facc76a76919

Technology area	Definition[109]	Exemplar devices and application
Open information sharing standards, platforms and protocols[145]	Using open and interoperable technologies and techniques to facilitate the sharing and exchange of information across different systems and platforms, including open data standards, such as XML and JSON, to ensure that data can be easily shared and integrated across different applications and platforms, as well as the use of open APIs and web services to enable real-time data exchange and integration.	Semantic modelling and standards for flood management Open-source information hubs Open-source earth observation platform (WASDI) National remote sensing platform Blockchain protocols Planetary computers
Organisational resource management tools[146]	The use of technologies and techniques to manage and optimise organisational resources and performance, such as human capital, financial resources and physical assets.	Social impact monitoring Micro-donation platforms
Peer-to-peer networks and citizen reporting platforms[147]	Digital platforms to enable individuals to connect and collaborate with each other, and to report and share information about issues affecting their communities. Peer-to-peer networks involve the use of decentralised systems (e.g. blockchain and peer-to-peer file sharing) and enable individuals to share and exchange information and resources without needing intermediaries. Citizen reporting platforms involve the use of digital platforms (e.g. mobile apps and social media) to enable individuals to report and share information about issues affecting their communities (e.g. crime, pollution and public health).	Interactive voice response platform for clean energy adoption Social media data crowd-sourcing Volunteered geographic information Community purchasing applications Household vulnerability survey platform (DASTAA) Community-based communication networks
Precision medicine[148]	Technologies and techniques to tailor medical treatment and care to individual patients based on their unique genetic, environmental, physical and lifestyle factors.	Precision medicine for anxiety disorder treatment Customised mobility aids

145 Chandola, Basu. 2022. 'Promoting Principles-Based Use of Technology in Humanitarian Assistance.' *ORF Issue Brief* 564. As of 6 August 2024: https://www.orfonline.org/research/promoting-principles-based-use-of-technology-in-humanitarian-assistance

146 OneRelief. 2017. 'Micro-donation platforms: An Overview.' Medium.com. As of 6 August 2024: https://medium.com/onerelief/micro-donation-platforms-an-overview-fe39129a6b43

147 Sudan, Sanjna & Anaswara Kovithal. 2023. 'Sixteen Technology-Driven Innovations Tackle Emergency and Humanitarian Challenges'. As of 6 August 2024: https://wfpinnovation.medium.com/sixteen-technology-driven-innovations-tackle-emergency-and-humanitarian-challenges-facc76a76919

148 United Nations International Children's Emergency Fund (UNICEF). 2024. *Precision health: emerging innovations for children and adolescents (Insight Report No. 3).* New York: UNICEF Office of Innovation. As of 6 August 2024: https://www.unicef.org/innovation/media/19681/file/Insights%20Report:%20Precision%20Health%20.pdf

Technology area	Definition[109]	Exemplar devices and application
Privacy-enhancing technologies[149]	Systems to protect the privacy and security of personal information, including encryption, anonymisation and pseudonymisation to protect data from unauthorised access and use, as well as the use of privacy-preserving data analysis techniques (e.g. differential privacy, to enable data analysis while protecting individual privacy).	Cryptosecure communications Privacy-preserving information-sharing services Cryptographically secured evidence Data anonymisation tools
Rapid/micro-scale health diagnostics[150]	Technologies that develop and deploy diagnostic tests that are fast, portable, and easy to use, including point-of-care diagnostic tests (e.g. lateral flow assays and microfluidic devices) that can be used in remote or resource-limited settings to diagnose infectious diseases, such as HIV, malaria and COVID-19, as well as non-communicable diseases, such as cancer and diabetes. Rapid/micro-scale health diagnostics are designed to improve access to timely and accurate diagnosis, particularly in low-resource settings, and to inform treatment and disease management decisions.	Rapid anaemia testing Malnutrition detection systems Microneedle sensors for biomarkers Smartphones for pathogen detection
Remote sensing instruments[151]	Using technologies and techniques to collect and analyse data about the physical environment from a distance. Remote sensing instruments are used in a variety of applications, such as environmental monitoring, disaster response and natural resource management, to inform decision making and improve understanding of the Earth's systems.	High-frequency radar Wide-band antennas and sensors High-frequency whistle applications Microwave radar detection for victim detection Radio-frequency identification

149 Chandola, Basu. 2022. 'Promoting Principles-Based Use of Technology in Humanitarian Assistance.' *ORF Issue Brief* 564. As of 6 August 2024: https://www.orfonline.org/research/promoting-principles-based-use-of-technology-in-humanitarian-assistance

150 World Food Programme (WFP) Innovation Accelerator. 2024. 'Optimus: Data-driven insights to save lives.' Innovation Accelerator. As of 6 August 2024: https://innovation.wfp.org/project/optimus;
Downs, Alex M., Adam Bolotsky, Bryan M. Weaver, Haley Bennett, Nathan Wolff, Ronen Polsky & Philip R. Miller. 2023. 'Microneedle electrochemical aptamer-based sensing: Real-time small molecule measurements using sensor-embedded, commercially-available stainless steel microneedles.' Biosensors and Bioelectronics 236. As of 6 August 2024: https://doi.org/10.1016/j.bios.2023.115408

151 Ozturkcan, Selcen. 2023. 'Technology and Disaster Relief: The Türkiye-Syria Earthquake Case Study.' In *Innovation - Research and Development for Human, Economic and Institutional Growth*. IntechOpen. doi:10.5772/intechopen.111612;
Marić, Josip, Carlos Galera-Zarco & Marco Opazo-Basáez. 2022. 'The emergent role of digital technologies in the context of humanitarian supply chains: a systematic literature review.' *Annals of Operations Research* 319: 1003–1044. As of 6 August 2024: https://doi.org/10.1007/s10479-021-04079-z

Technology area	Definition[109]	Exemplar devices and application
Rescue robotics[152]	Robotic systems – computer-aided or controlled mechanical systems that interact with the physical world – designed to assist in humanitarian rescue contexts by providing rescuers with an ability to sense and act at a distance from a site. They are often used in contexts where the environment is damaged, dangerous or inaccessible.	Search and rescue robots Building inspection and debris removal robots
Shelter cooling systems[153]	Novel systems that promote heat transfer from within to outside of a shelter for the purposes of cooling its contents or inhabitants. The mediums and mechanisms of heat transfer can vary depending on the system, for example including heat-resistant materials and air-to-air, air-to-fluid or fluid-to-fluid convection.	Bio-inspired cooling technologies (CAG) Solar-powered cooling systems
Smart translation and communication tools[154]	Systems that draw upon technologies including audio transmission and receivers, user interface applications and translation algorithms to enable the automation of communication across users in different languages, and/or with automated agents providing information.	Chatbot interfaces Humanity Link platform Automated interactive voice response systems

152 Foy, Kylie. 2021. 'Exploring the future of humanitarian technology.' *MIT News*. As of 6 August 2024: https://news.mit.edu/2021/exploring-future-humanitarian-technology-0603;
Ozturkcan, Selcen. 2023. 'Technology and Disaster Relief: The Türkiye-Syria Earthquake Case Study.' In *Innovation - Research and Development for Human, Economic and Institutional Growth*. IntechOpen. doi:10.5772/intechopen.111612

153 Cai, Chenyang, Wenbo Chen, Zechang Wei, Chunxiang Ding, Bianjing Sun, Christoph Gerhard, Yu Fu & Kai Zhang. 2023. 'Bioinspired "aerogel grating" with metasurfaces for durable daytime radiative cooling for year-round energy savings.' *Nano Energy* 114. As of 6 August 2024: https://www.sciencedirect.com/science/article/abs/pii/S2211285523004627?via%3Dihub;
ColdHubs. 2021. 'Enabling Food Storage in Displacement Camps.' As of 6 August 2024: https://humanitariangrandchallenge.org/innovator/cold-hubs/

154 Fosso Wamba, Samuel, Maciel M. Queiroz, Samuel Roscoe, Wendy Phillips, Dharm Kapletia & Arash Azadegan. 2021. 'Guest editorial: Emerging technologies in emergency situations.' *International Journal of Operations & Production Management* 41(9): 1405–1416. As of 6 August 2024: https://doi.org/10.1108/IJOPM-09-2021-904;
Sudan, Sanjna & Anaswara Kovithal. 2023. 'Sixteen Technology-Driven Innovations Tackle Emergency and Humanitarian Challenges'. As of 6 August 2024: https://wfpinnovation.medium.com/sixteen-technology-driven-innovations-tackle-emergency-and-humanitarian-challenges-facc76a76919

Technology area	Definition[109]	Exemplar devices and application
Telemedicine[155]	Telemedicine (alternatively referred to as Telehealth) refers to 'the use of electronic information and communications technologies to provide and support health care when distance separates the participants'.[156] This encompasses remote sensing, communication and visualisation technologies and applications, often integrated with medical devices or robotics.	Virtual clinics Malnutrition detection software Remotely-assured ultrasound Telemedicine glasses Tele-microbiology
Tissues and prosthetics manufacturing[157]	The use of manufacturing techniques and systems, including additive manufacturing and bioengineering and manufacturing, to produce biological tissues (groups of similar cells that act together to perform biological functions) and prosthetics (artificial body parts intended to restore functions) for use in healthcare.	3D-printed prosthetics and orthotics Bioinks for bone tissues
Unmanned aerial vehicles and drones[158]	'An aircraft that carries no human pilot or passengers. UAVs—sometimes called drones—can be fully or partially autonomous but are more often controlled remotely by a human pilot.'[159] These systems can be integrated with other technologies such as computer vision and sensing or lighting to perform additional functions.	Supply distribution drones Search and rescue drones Intelligent surveillance drones Drone-enabled crisis visualisation Drone-enabled lighting networks Light-weight (LPDE) drones

155 Chandola, Basu. 2022. 'Promoting Principles-Based Use of Technology in Humanitarian Assistance.' *ORF Issue Brief* 564. As of 6 August 2024: https://www.orfonline.org/research/promoting-principles-based-use-of-technology-in-humanitarian-assistance

156 Field, M. J. 1997. 'Telemedicine: A guide to assessing telecommunications in healthcare.' *Journal of Digital Imaging* 10(1): 28. As of 6 August 2024: https://doi.org/10.1007/BF03168648

157 European Commission, Directorate-General for Research and Innovation (DG RTD). 2020. 'EIC Horizon Prize on Affordable High-Tech for Humanitarian Aid: Commission awards five outstanding solutions.' As of 6 August 2024: https://research-and-innovation.ec.europa.eu/news/all-research-and-innovation-news/eic-horizon-prize-affordable-high-tech-humanitarian-aid-commission-awards-five-outstanding-solutions-2020-09-24_en

158 Fang, Yongcong, Mengke Ji, Bingyan Wu, Xinxin Xu, Ge Wang, Yanmei Zhang, Yingkai Xia, Zhe Li, Ting Zhang, Wei Sun & Zhuo Xiong. 2023. 'Engineering Highly Vascularized Bone Tissues by 3D Bioprinting of Granular Prevascularized Spheroids.' *ACS Applied Materials & Interfaces* 15(37): 43492–43502. As of 6 August 2024: https://doi.org/10.1021/acsami.3c08550;
Foy, Kylie. 2021. 'Exploring the future of humanitarian technology.' *MIT News*. As of 6 August 2024: https://news.mit.edu/2021/exploring-future-humanitarian-technology-0603;
Fosso Wamba, Samuel, Maciel M. Queiroz, Samuel Roscoe, Wendy Phillips, Dharm Kapletia & Arash Azadegan. 2021. 'Guest editorial: Emerging technologies in emergency situations.' *International Journal of Operations & Production Management* 41(9): 1405–1416. As of 6 August 2024: https://doi.org/10.1108/IJOPM-09-2021-904

159 RAND. n.d. 'Unmanned Aerial Vehicles.' Rand.org. As of 6 August 2024: https://www.rand.org/topics/unmanned-aerial-vehicles.html

Technology area	Definition[109]	Exemplar devices and application
Virtual and augmented reality[160]	Technologies that enable users to experience immersive digital environments and interact with virtual objects and information. Virtual reality typically involves using head-mounted displays and other sensory inputs to create a fully immersive digital environment, while augmented reality involves the overlay of digital information onto the real world through the use of mobile devices and other technologies.	Digital twins Disaster simulation tools Virtual health worker training Haptic technologies for remotely operated vehicles Humanitarian visualisations
Water harvesting[161]	Systems for collecting and storing rainwater or other sources of water, such as groundwater or surface water, for later use. This can be done through various methods, such as the use of rain barrels, cisterns or other storage tanks, as well as the construction of catchment areas, such as ponds or reservoirs, to capture and store water runoff. Water harvesting is often used in areas with limited water resources or in regions where droughts or other water shortages are common.	Cloud seeding Air water harvesting

160 Grieves, Michael. 2022. 'Intelligent digital twins and the development and management of complex systems [version 1; peer review: 4 approved].' *Digital Twin* 2(8). As of 6 August 2024: https://doi.org/10.12688/digitaltwin.17574.1

161 Fontes de Meira, Luciana & Omar Bello. 2020. 'The use of technology and innovative approaches in disaster and risk management: a characterization of Caribbean countries' experiences.' *Studies and Perspectives – ECLAC Subregional Headquarters for the Caribbean* 93. As of 6 August 2024: https://repositorio.cepal.org/server/api/core/bitstreams/d1f94a03-ab00-4b25-9b3d-98239b5327c1/content; Oksen, Peter & Lise Favre. 2020. 'Innovative technology in the Water, Sanitation and Hygiene (WASH) sector.' Global Challenges in Focus, World Intellectual Property Organization. As of 6 August 2024: https://www.wipo.int/edocs/pubdocs/en/wipo_pub_gc_20_1.pdf

Annex B. Web-reading taxonomy for the deep dives

Table B.1 presents an overview of the web-reading activities conducted as part of the deep-dive development under Phase 2 (see Section 3.4). Initial inputs were identified by the study team through targeted searches and subsequently supplemented by AI-enabled web-reading activities.

Table B.1 Overview of deep-dive technology taxonomy

Technology area	Area definition	Technology taxonomy terms identified through project horizon scanning	Additional technology taxonomy terms identified in literature
Privacy-enhancing technologies[162]	Systems to protect the privacy and security of personal information, including encryption, anonymisation and pseudonymisation to protect data from unauthorised access and use, as well as the use of privacy-preserving data analysis techniques (e.g. differential privacy, to enable data analysis while protecting individual privacy).	Secure communications Privacy-preserving information-sharing services Cryptographically secured evidence Data anonymisation	Data obfuscation Encryption Federated analytics Distributed analytics Data accountability Pseudonymisation Differential privacy Data minimisation Privacy personalisation Anti-tracking Secure computation Privacy preservation certification Statistical disclosure control Self-destructing data systems

162 Organisation for Economic Cooperation and Development (OECD). 2023. 'Emerging privacy enhancing technologies: current regulatory and policy approaches.' *OECD Digital Economy Papers* 351. As of 6 August 2024: https://www.intgovforum.org/sites/default/files/webform/igf_2023_open_forums_town_hall_s/243938/bf121be4-en.pdf; Javed, Ibrahim T., Fares Alharbi, Tiziana Margaria, Noel Crespi & Kashif N. Qureshi. 2021. 'PETchain: A Blockchain-Based Privacy Enhancing Technology.' *IEEE Access* 9: 41129–41143. As of 6 August 2024: https://ieeexplore.ieee.org/document/9373373;
Kaaniche, Nesrine, Maryline Laurent & Sana Belguith. 2020. 'Privacy enhancing technologies for solving the privacy-personalization paradox: taxonomy and survey.' *Journal of Network and Computer Applications* 171: 102807. As of 6 August 2024: https://hal.science/hal-03990971v1/file/_JNCA____Survey_PETS.pdf

Technology area	Area definition	Technology taxonomy terms identified through project horizon scanning	Additional technology taxonomy terms identified in literature
Service coordination and aggregation platforms[163]	The use of technologies and techniques to coordinate humanitarian aid and response efforts in times of crisis or emergency, including the use of digital platforms and mobile applications to aggregate information on needs and resources. These platforms can also span the pooling and access to shared resources or services for humanitarian organisations (e.g. logistics and transportation systems), and the use of communication technologies to coordinate multi-organisation response efforts among humanitarian organisations and government agencies.	Security service aggregators Emergency response coordination platform Dynamic field operations platform	Supply-chain management Procurement management Donation management Service coordination Aggregator platforms Inventory management Volunteer coordination Information alignment and coordination Pool sharing Operational coordination Security cooperation

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Technology area	Area definition	Technology taxonomy terms identified through project horizon scanning	Additional technology taxonomy terms identified in literature
Camp monitoring systems[164]	Systems to monitor and manage refugee camps, detention centres and other temporary settlements including deploying sensors, cameras and other monitoring devices to track the movement of people and goods, as well as using data analytics and machine learning to identify patterns and trends in camp activities. Camp monitoring systems are designed to improve the safety, security and well-being of people living in temporary settlements, and to help humanitarian organisations and governments respond more effectively to crises and emergencies.	Fire alert systems Water supply monitoring Perimeter monitoring	Camp environmental monitoring Camp remote sensing Space-based monitoring Camp visual technologies Camp spatial technologies
Advanced manufacturing systems[165]	Advanced manufacturing techniques offer increased geometry complexity, energy and material usage efficiency improvements, and an expanded palette of materials as compared to conventional manufacturing approaches. Advanced manufacturing (AM)-produced parts can experience wide variations in the final microstructure, and these microstructure variations significantly impact the parts' performance.[166]	3D printing for field manufacturing Printable electronics and hardware 4D printing Multi-material 3D printing Underbody shield composites 3D printing of inorganic nanomaterials	Advanced manufacturing Additive manufacturing Distributed manufacturing Field manufacturing Direct energy deposition Binder jetting Material jetting Material extrusion Powder bed fusion Sheet lamination VAT photopolymerisation

164 Zwijnenburg, Wim & Ollie Ballinger. 2023. 'Leveraging emerging technologies to enable environmental monitoring and accountability in conflict zones.' *International Review of the Red Cross* 105(924): 1497–1521. As of 6 August 2024: https://doi.org/10.1017/S1816383123000383

165 Ansell, Troy Y. 2021. 'Current Status of Liquid Metal Printing.' *Journal of Manufacturing and Materials Processing* 5(2): 31. As of 6 August 2024: https://doi.org/10.3390/jmmp5020031

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Technology area	Area definition	Technology taxonomy terms identified through project horizon scanning	Additional technology taxonomy terms identified in literature
Early-warning systems[167]	Using technologies and techniques to detect and alert people about potential natural disasters (e.g. earthquakes, tsunamis, hurricanes, floods), typically using sensors, satellite imagery and other monitoring devices to detect changes in environmental conditions, as well as the use of automated algorithms and machine learning to analyse data and issue warnings in real-time. Automated disaster early-warning systems are designed to improve the speed and accuracy of disaster response, and to help minimise the impact of disasters on people and communities.	Flood early-warning systems Automated mobile alert systems Adaptive response messaging Landslide prediction and warning system	Early-warning system (EWS) Participatory early warning Multi-hazard early warning (MHEWS) Disaster warning Disaster detection Disaster observation Disaster monitoring Warning communication Warning dissemination

167 ITU News. 2023. 'Early warning systems for all by 2027.' As of 6 August 2024: https://www.itu.int/hub/2023/03/early-warning-systems-for-all-by-2027/