The 'PROTECT' Essential Elements in Managing Crisis Data Policies

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ABSTRACT

Based on a literature review, policy study, and a conference session discussion, this paper systematically analyzed seven predominant elements in crisis data policies, namely 'people, resources, operation, technology, ethics, communication, and trust,' abbreviated as the 'PROTECT' essentials. As a guiding checklist for crisis data policy, implementing the 'PROTECT' essentials should follow the guiding principles, in which people should be united to understand each other better and get prepared for intelligible data resources; the operation of crisis data work should be uniquely tailored to scenarios, with promising IT adoption guided by utilitarian ethics; crisis communication should be prompt and unambiguous; trust between people and machines should be sustainable. These can be summarized as the 'UPs' principles. All these efforts together contribute to a sustainable crisis data ecosystem. Selected case studies on the COVID-19 pandemic, and the February 6, 2023 Türkiye-Syria earthquake, validate how the 'PROTECT' essential framework helps guide crisis data work. We hope the 'PROTECT' essentials and the implementation guidelines could provide insights into future crisis data policies.

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1 INTRODUCTION

Data plays an important role in global governance (Hansen & Porter 2017), such as tackling grand challenges in pandemics and natural hazards and achieving the United Nations Sustainable Development Goals (SDGs). Appropriately using and reusing data could break the silos across regions and domains (Science International 2015), thus helping vulnerability mitigation. For example, data helps scientists foster crisis responses timely by intelligible technology deployment. Furthermore, data supports governments' swift decision-making by linking various social and public factors under the big data landscape. Immediate access to real-time data provides essential knowledge to prevent panic attacks and prepare communities for crises. Moreover, data also promotes post-disaster recovery and social reconstruction through the penetration of the digital economy into the entire societal world.

According to the International Science Council (ISC) and United Nations Office for Disaster Risk Reduction (UNDRR) (2020) and Murray et al. (2021), there are 302 types of hazards, ranging from hydrometeorological, extraterrestrial, geological, environmental, chemical, and biological to technological and societal domains, and the open-ended list is still growing. Among different crises, data takes a predominant role in tackling challenges through the full crisis management cycle. Thus, ensuring that crisis data policies are complete, effective, timely, and perspicacious to resolve critical crises is crucial. Besides, the *UNESCO Recommendation on Open Science* (2021) also pours a richer connotation into the crisis data work. Facing this background, the CODATA International Data Policy Committee (IDPC) has organized a series of hybrid discussions since October 2022 (Basbug, Crawley & Murray 2023) to address key data policy issues for Open Science in crises. As the second of the series, the 'EOSC Symposium 2022 CODATA IDPC Data Policy for Open Science in Crises' was launched in Prague, Czech Republic, on November 16, 2022. This session focused on data policies in the context of Open Science pinpointing several issues, such as ethics, human rights, data governance, and lessons from COVID-19. Several suggestions have been proposed for improving crisis data policy design and development.

However, considering so many discussions, what is the comprehensive overview that includes all the critical elements in data policy design in times of crisis? How do these predominant elements connect and work systematically to respond to emergencies? What are the implementation precautions and guidelines under the Open Science umbrella? To better illustrate these questions, this paper adopts a 'hypothetic-deductive' approach (Nola 2007) to summarize the crisis data policy essentials based on literature review and policy study. Then, further discussion focuses on implementing this crisis data policy essential framework driven by the prioritized research question mentioned above. Afterward, selected case studies are used to validate the essential framework of the crisis data policy. Finally, lessons learned and envisioned future work will contribute to next-step actions.

2 LITERATURE REVIEW

Lightweight literature review and policy studies revealed influential factors and examples of guiding rules in crisis data management, ranging from peoples' roles, resource preparedness, process management throughout crisis stages, ICT adoption, ethical and cultural considerations, and communication, as well as others.

The main contributors that drive crisis data work are those great players in crisis, such as the United Nations and affiliated agencies, the International Organizations and their strategic partners, the national, regional, and institutional entities, industrial partners, the social public, and others. Subject to different collaboration models, these contributors share different roles, responsibilities, and rights, with people-centered approaches adopted for efficient and effective disaster risk reduction practices (UN 2015). To ensure nobody is left behind, such people-centered approaches especially highlight the involvement of vulnerable groups, such as 'women, children, and youth, people with disabilities, poor people, migrants, indigenous peoples, volunteers, the community of practitioners, and elderly persons' (UN 2015: paragraph 10p). To support the design and implementation of data policies for disaster risk reduction, people in crisis should insist on rules such as diverse involvement (Stabile et al. 2022), leadership roles of professional entities (Hazaa et al. 2021), unity of effort (FEMA 2017), and others.

Further, looking into the policies guiding various crises work, we see data plays an essential role. For example, the *Sendai Framework for Disaster Risk Reduction* states that 'disaster risk reduction requires a multi-hazard approach and inclusive risk-informed decision-making based on the open exchange and dissemination of disaggregated data, including by sex, age, and disability, as well as on easily accessible, up-to-date, comprehensible, science-based, non-sensitive risk information, complemented by traditional knowledge' (UN 2015: paragraph 19g). As a public good (WHO 2020a), data enables better disaster risk management by identifying data management challenges and establishing '*baseline data with integrated data repository*' (ISC et al. 2020). To help prepare for crisis response, open data, such as open government data, should be 'non-discriminatory' for the sake of 'integrity, provenance, attribution, and openness' (OECD 2021) and diversified with other relevant resources such as information, knowledge (Benaben et al. 2017; Rogova 2016). Besides, these resources should be interconnected, flexible, and interpreted (Roller, Rose & Verbree 2015) for better understanding in unexpected circumstances.

To better organize stakeholders and handle data-relevant resources in crisis, process management should feature the appropriate design of conceptual framework (Haq, Aima & Bhasin 2011), response schema (Benaben et al. 2017), lifecycle data management throughout crisis stages for preparedness, response, and recovery (Munawar et al. 2022). Guiding rules highlight distributed, accurate, comprehensive, frequent, flexible, strong, and responsible governance of data work (BIS 2013; Essendorfer et al. 2020). Methods and tools are further developed to strengthen the crisis process management. For example, a 'DISE' model compromising big data (D), impact module (I), strategy module (S), and evaluation model (E) has been proposed, serving as a tool for crisis monitoring (Sun et al. 2022). 'Systemness' depicts an approach that pinpoints the overall quality and efficiency of management during the COVID-19 crisis (Waldeck, Srivastava & Picken 2020).

Digital technology extends the capacity for crisis data work by handling real-time, converged, scalable, disciplinary data in support of crisis. Examples include adoption of network technologies for automated data exchange (Black, Moncada & Herstad 2021; Panda 2015), sensors for data capture (Mora & Divitini 2014), big data technologies for data mining (Zagorecki, Johnson & Ristvej 2013), visualization, analysis, and artificial intelligence (Shah 2015) for hazard management prediction and decision making, blockchain for data trusts (Filippi, Mannan & Reijers 2020; Akram MW et al. 2023), cloud federation for data interoperability, etc. Moreover, effectively implementing data platforms, such as disaster loss database systems with validated data and inventories, is essential for identifying and tracking disaster risk patterns and promoting the 'online sharing of resources, training materials, and other forms of support' in crises (UNDRR & UNDP 2022). Guiding rules for crisis ICT highlight the full exploration of cutting-edge technologies, unified standardization, and compound technical solutions to address data challenges throughout crisis stages.

Furthermore, legal, ethical, and cultural issues leverage public good and individual rights (RDA 2020a) with special focuses on data gaps, research ethics (Pisani et al. 2019), human conflict, and bias (Paulus et al. 2022). Meanwhile, risk communication, a two-way interaction between professionals and non-professionals, is also vital for timely decision-making in response to potential emergencies (WHO 2019). It promotes exchange and negotiation concerning hazards, risks, and risk-related factors (WHO 2020b) and aligns with social media and other social networks (Spence, Lachlan & Rainear 2016; Avvenuti et al. 2020; Park 2022). Crisis communication highlights timeliness, accessibility, relevance (Reuter et al. 2017), clarity, usefulness (BIS 2013), and others against information asymmetry in crises.

The review above identified several emerging topics relevant to crisis data work. In the face of crises, all these essentials should be neatly integrated as a comprehensive checklist to help design adaptive crisis data policies. Such a checklist should identify potential priorities in crisis data work and be adaptable to specific scenarios, thus promoting the real world's crisis data policy design and development.

3 THE 'PROTECT' ESSENTIALS

Based on the literature review and data works' experiences, we grouped data policy principal elements into the 'PROTECT' essentials (see Figure 1). The following subsections elaborate on each of these elements. It is important to consider every letter of the 'PROTECT' essential before, during, and after crises.

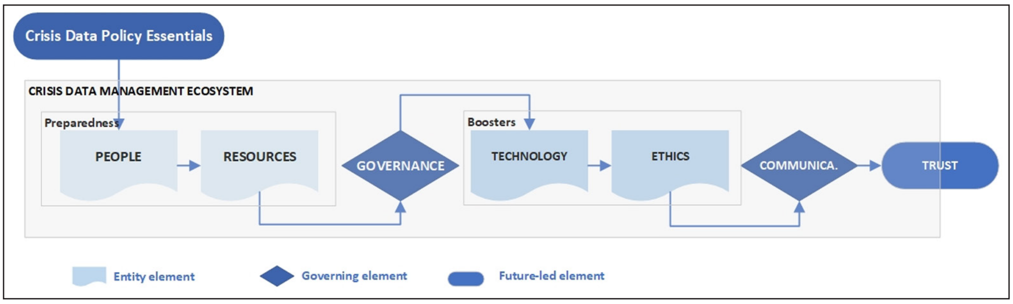

Figure 1 The 'PROTECT' essentials for data policy design and redesign.

3.1 PEOPLE

The design and development of crisis data policy follow several rules, among which people's needs should be initially prioritized. Thus, the top concern for crisis data policy is to identify that it is by whom and for whom. 'People,' namely the stakeholders, are essential drivers who learn from the past to face current risks and prepare for the future. Crisis stakeholders include internal and external ones (Bundy et al. 2017; van der Meer et al. 2017; Ndlela 2019; Azevedo 2022). Internal stakeholders are those suffering loss from the crises directly, including individuals and institutions, like the government and the supporting service departments (i.e., the health and medical department, the social governance department, the scientific and technical department, etc.) which assume clear responsibilities in crisis management; research institutions which provide potential technologies and solutions to tackle crises; social enterprises, such as social media, nonprofit organizations, and commercialized enterprises, the general public, and others. Stakeholders' crisis roles are diverse but sometimes overlapped, with some obliged to fulfill duties and others voluntarily. Considering the unbalanced power in decision-making, underrepresented groups, such as women and kids, indigenous people, and other data-disadvantaged groups, should be addressed. External stakeholders indicate those who may be affected by crises indirectly. It includes communities exposed to the knock-on effects of geography, economy, science, social governance, etc.

'People' highlights the connectivity between multiple stakeholders and pinpoints the importance of inclusive enrollment of representatives in crisis data policies. Moreover, clarifying obligations and rights reserved for different stakeholders should be as clear as possible to support decision-making, thus ensuring efficient interaction between domains, regions, and organizations. Besides being inclusive, the interaction between stakeholders should also feature mutual respect, especially for 'community or individual decisions outside the preferences of authorities' (UNHCR 2014: article 65).

3.2 RESOURCES

Uncertainty is the only known parameter in crises, and data-centric resources should be prepared beforehand, especially when 'People' are ready on board, thus making crisis response timely, reliable, and sustained. 'Resources' mainly refer to the data-centric and social capital (Adler & Kwon 2002; Lindon et al. 2002). These include knowledge-based data and affiliated services, data infrastructures, and financial resources to support in-time and long-term capacity building. To support crisis risk reduction, data and related research resources and services should be prioritized as first-class public assets (CODATA et al. 2019). Hazard data are precious in getting people knowledgeable and prepared for disaster mitigation (Gündoğan & Ata 2021). Besides, data infrastructures, data systems, facilities, and other physical and virtual platforms constitute another essential resource in implementing data policies. In crises, data infrastructures are those platforms where people get knowledge and experience from the past and prepare technically for current and future crisis data stewardship. Furthermore, emergency data funding is also a compulsory resource for redesigning data policies and reusing data in the crisis framework.

3.3 OPERATION

'Operation' indicates the crisis management processes and execution based on crisis prerequisites. The efficient operation of people and resources is critical to resilient disaster mitigation. Lack of efficient operation may lead to Information asymmetry among stakeholders, overlapping management of emergency plans, exclusiveness of crisis decision-making, and chances of crisis resources decay or chaos when facing risky scenarios. Thus, sound operation of crisis resources and people is urgently needed. Compared to 'management' or 'governance,' the neutral concept of operation is borrowed here to signify its functionality. This way, managing human and data resources is more crisis-saving and object-oriented, characterizing continuousness and sustainability. Such 'operation' may include interoperable protocols to guarantee data reusability in risks, design, and development of crisis data management plan (Black, Moncada & Herstad 2021), lifecycle data governance models for city resilience, metrics and incentives for data visibility, reusability, accountability, and ethics in favor of responsible Open Science. The operation calls for people's engagement and data resource preparedness and deserves evolving processes to minimize crisis risks.

3.4 TECHNOLOGY

'Technology,' acting as a booster in tackling the crisis, mainly refers to all the information and communication technologies facilitating intelligible data exploration in crises. Technology deployment may cover the whole emergency management cycle, ranging from prevention, preparedness, response, and recovery (ISC & UNDRR 2020), and poses a great impact on other crisis management essentials, such as 'resources,' 'operation,' and 'communication.' For example, automatic technologies and devices like robots and sensors may help facilitate crisis data capture for early warnings and data processes, especially in extreme situations (Lin, Huang & Putranto 2022; Chanthujan et al. 2022); artificial intelligence and intelligible big data analytics may raise awareness and understanding of potential risks to save losses (Bennett 2019); spatiotemporal location big data technologies help public epidemic intervention (Li et al. 2020); cloud computing and edge computing connect data infrastructures for timely decision making (Shivakumar, Raju & Hannah 2010; Velev & Zlateva 2012); open metrics support hazard monitoring thus providing validation for wisely funding resources arrangement; teleconference and social media technologies facilitate swift communication of crisis data, and information and knowledge for capacity building (Hassankhani et al. 2021). Technologies also include designing and developing interoperable standards (López et al. 2019; UNICEF 2019) to help bridge gaps across domains and regions for effective data fusion, robust data infrastructure development, connection with other resources, such as big data resources, and data infrastructures to tackle various crises.

3.5 ETHICS

To generate appropriate and timely responses to crises, ethics provides maximum benefit to the largest number of people. Among these, crisis data ethics addresses ethical principles and values of data gathering, data processing, use and reuse of data, and individual right to information (UN 2021a). To mitigate the vulnerability, ethical guidance should balance stakeholders' interests by incorporating risks of overruling human dignity and fundamental human rights for the greater good. Principles of legality, the rule of law (UN nd.), and the principle of proportionality (UNOLA 2023) are essential to find and maintain this balance by valuing individual rights, such as privacy, confidentiality, and rights to data and information while securing maximum benefits that fortify the community's trust in authorities. Data ethics should also reinforce the potential of individuals by fully exploring data value for risk assessment and response.

3.6 COMMUNICATION

Guaranteed as a fundamental human right, information freedom is critical in emergencies. Thus, 'communication' of data facts, risk information, and hazard knowledge is another booster in crisis management. Communication may be assigned many roles in crises, such as enhancing capacity building for hazard preparedness, raising awareness by early warnings, exchanging knowledge for swift hazard response, and gaining experiences to save secondary losses for disaster recovery. Appropriate communication will reduce crisis losses, while at the same time, it can become a serious hazard and hinder crisis response and recovery. Communication among stakeholders should always be reliable, sustained, open, and knowledgeable to reduce chaos. For example, communication between scientists should be datafied to guarantee innovative knowledge discovery for disaster mitigation as much as possible. Communication with the public should rely on data and knowledge while remaining open-ended; thus, citizens would better understand what is happening and how to prepare and respond soundly. Communication between collaborative organizations should be inclusive and sustained, aiming for larger, substantial alignment within and after crises. Communication may also adopt a dynamic approach, empowered by the ongoing scale of data and knowledge production, boosted by Open Science, technical-driven social media (Stephens & Malone 2010), and others.

3.7 TRUST

'trust' is the ultimate goal for the 'PROTECT' elements. It may include consensus on data operation strategies, converged ways to deploy data resource-supported technologies, and sufficient and timely information sharing by communications. Trust may also include the lessons we learn from the past and to be adopted in the future. It comes from people and is boosted by technology. 'trust' might be established gradually through iterative rounds of crisis data operation while reinforced by dialogues between interested parties. Mutual trusts strengthen every data system by co-building robust data ecosystems. Thus, all six previous elements can finally be mapped into the last 'T' as 'trust'. For people, 'trust' amid consensus is enriched in dialogues and understanding between internal and external organizations. As for resources, 'trust' depends on reliability, seamlessly indicating high-quality control of resources. For operation, 'trust' means efficiency and effectiveness. In technology, 'trust' refers to being interoperable between machines and intelligible for humans. 'trust' will guide the sound management of ethics in communication with a better understanding of turbulent disaster emergency management processes through information symmetry.

4 IMPLEMENTATIONS

4.1 IMPLEMENTING THE 'PROTECT' ESSENTIALS

Based on the discussion above, seven essentials have been identified to prepare crisis data policies. Under the open-science umbrella, with the FAIR principles (Wilkinson et al. 2016; Davidson et al. 2019), the TRUST principles (Lin et al. 2020), and the CARE principles (Carroll, Rodriguez-Lonebear & Martinez 2019; Carroll et al. 2020) considered, implementing this 'PROTECT' checklist should follow several rules (see more in Table 1).

Table 1 'UPs' guidance for 'PROTECT' implementation.

COMPONENTS	EXPECTED	NOTES
People	**U**nited	In the spirit of Open Science, 'People' depicts all the community roles for crisis management. Such organizing work should be 'United,' thus leading to inclusive, open dialogues.
Resources	**P**repared	'Prepared Resources' should be multifaceted, converged neatly, and fair to reuse in crises.
Operation	**U**nique	'Operation' of data work should always be 'Unique' and thus tailored to the changing crisis environment.
Technology	**P**romising	'Promising Technology' refers to cutting-edge adoption to address potential crisis data challenges and other barriers. It should be resilient enough to tackle multifaced datasets across regions and domains and robust enough to meet the needs today and in the future.
Ethics	**U**tilitarian	'Ethics' should be 'Utilitarian,' complying with proportionality, reciprocal legality, and the rule of law. The devastating conditions of crises evoke irreversible damages to fundamental human rights, thus proposing the need to overrule all IPRs or related rights of individuals regarding data and urgent requests for maximizing the overall benefits and protecting rights and freedoms.
Communication	**P**rompt and **u**nambiguous	From data to knowledge and wisdom, 'Communication' should be 'Prompt' to save losses caused by information asymmetry, 'Unambiguous' for knowledge delivery, thus consolidating mutual trusts for social governance, and eligible for enhanced data literacy empowerment in the societal community.
Trust	**S**ustainable	'trust' between people and machines is 'Sustainable' in the short and long term. Mutual trust should involve multilateral participation and benefit local and international interested parties to ensure such sustainability.

United 'people' refers to the inclusive involvement of multiple interests before reaching a consensus for further crisis data actions. **Prepared 'resources'** guarantee the sufficiency and relevance of data and treasures throughout crisis stages, among which crisis resources should be multifaceted, neatly converged, and be FAIR to reuse. **Unique 'operation'** highlights the flexibility of operation, which is adaptive to the changing crisis environment and stages. **Promising 'technology'** unlocks data potentials by extensively and effectively utilizing multifaced datasets across regions and domains to meet the needs today and in the future. **Utilitarian 'ethics'** emphasizes doing 'the most good' (CEBE nd.) to bridge data gaps to offset the imbalance in abrupt situations. **Utilitarian 'ethics'** involves the interests of multiple groups, especially those data disadvantaged, and diversifies the scope of utility definition. It covers the interests of currently vulnerable groups at most and the long-term sustainability of the most beneficiaries. Besides, it also gauges the value of crisis data work through economic and social-cultural ways and maintains the dynamic balance between interest groups to ensure a shared future for sustainable development. Besides, **'communication'** of data, information, and knowledge should be **prompt** to save losses caused by information asymmetry, **unambiguous** to consolidate mutual trusts for social governance, and eligible for enhanced data literacy empowerment in the societal community. **Finally, sustained 'trust'** (Cambien 2017; Christensen & Lægreid 2020; BOHAČEK 2022) addresses the necessity of co-building trustworthy data ecosystems. All these analysis could be summarized as the "UPs" principles. Based on a shared understanding, these guiding principles will ensure the consensus between different stakeholders, consistent intelligibility between humans and machines, and sustainability in the short term and long term.

Within this 'PROTECT' essential framework, we see people and resources as the first-class capital we possess to face any crisis. Therefore, they should always be jointly prepared beforehand. Besides, technology and guiding ethics should be ready to ensure the efficiency and effectiveness of crisis data work. Moreover, operation and communication connect different capitals in systematic and iterative ways, in which each component should better adjust to crises, thus contributing to the sustainable, trustworthy crisis data ecosystem for crisis preparedness, response, and recovery (Munawar et al. 2022).

4.2 CASE STUDIES

To better illustrate how the 'PROTECT' essentials guide crisis data, we chose the COVID-19 case, and the February 6, 2023 Türkiye-Syria earthquake, to reveal global, regional, and national data efforts in mitigating vulnerabilities. The two cases provide real-world scenarios for 'PROTECT' adoption.

4.2.1 Crisis data management during COVID-19

COVID-19, which broke out in late 2019, provides a typical scenario where lifecycle data management and sharing play a decisive role. During this pandemic, all worldwide citizens have been involved, facing the most challenging moments, not only direct threats to lives and health but also secondary hazards in political disputes across regions, geopolitical conflicts, extreme poverty and hunger, deterioration of living environment, and worldwide economic recession. COVID-19 teaches us many lessons, and data policy design and development, are among the list. Luckily enough, starting as early as late 2019, joint data efforts are also worldwide to prepare for vulnerabilities.

Stakeholders involved in COVID-19 are the broadest, with conversation and collaboration flourishing like never before. Governments, academic entities, social enterprises, citizens, and others are all included in pandemic data capture, data technology development, infrastructure construction, and knowledge dissemination across domains and regions (Bernardo et al. 2021; WHO 2020c; WHO 2020d) ('people'). Such collaborations have been broadened from local to regional and international scopes (Bump, Friberg & Harper 2021), with multifaceted collaboration in the governance, technical adoption, and communication of crisis data, information, knowledge, and others (WHO 2020c; WHO 2020e).

Besides, in line with the International Health Regulations (2005), WHO began collecting and reporting COVID-19 data before the end of 2019, with statistics from official health ministries, social media accounts, WHO regional-specific dashboards, and other WHO-related data reports ('resources' on data). Latest data are shared through the WHO Coronavirus (COVID-19)

Dashboard[1] for knowledge dissemination. Volunteer data collection also depicts other snowball work, such as the Coronavirus Tracking Global Dashboard by Johns Hopkins Coronavirus Resource Center, enhanced disaster monitoring platform ('resources' on data systems) by DesInventar[2], and multi-dimensional data support for COVID-19 prevention. As for funding clusters (i.e., OCHA Financial Tracking Service platform[3] ('resources' on crisis data funding), the global and national emergency investments cover disaster mitigation supports driven by the use of risk information systems (i.e., UN Secretary-General launched a Global Humanitarian Response Plan for COVID, GHRP), crisis monitoring and evaluation, big-data methodology exploration (NSFC 2020), enhanced laboratory systems construction and risk communication (KFF 2020), as well as others.

'Operation' of COVID-19 data and related issues is crucial to facilitate crisis management. Among all the efforts in tackling such global challenges, the United Nations, and many international, intergovernmental organizations and national, regional, and domain entities are leading data policy design and development throughout the pandemic (see examples in Table 2). The operation of COVID-19 data also popularized open and collaborative research models, such as those between governments and citizens for data capture and dissemination and those of research entities and social and commercial enterprises for data exploration and science discovery.

Table 2 International examples of data policies through the pandemic.

TITLE	PUBLISHER AND YEAR	WORD FREQ. FOR 'DATA.'
UN Comprehensive Response to COVID-19: Saving Lives, Protecting Societies, Recovering Better (Third Edition)	(UN 2021b)	24
Review of COVID-19 Disaster Risk Governance in Asia-Pacific: Towards Multi-Hazard and Multi-Sectoral Disaster Risk Reduction	(UNDRR 2020a)	6
UNDRR Asia-Pacific COVID-19 Brief: Combating the Dual Challenges of Climate-Related Disasters and COVID-19	(UNDRR 2020b)	1
Global Assessment Report on Disaster Risk Reduction 2022—Our World at Risk: Transforming Governance for a Resilient Future	(UNDRR 2022a)	407
UNDRR Americas & Caribbean COVID-19 Brief: Science and Technology for DRR in the Context of COVID-19	(UNDRR 2022b)	3
Policy Brief: Building Trust Through Risk Communication and Community Engagement	(WHO 2022)	2
Climate-Related Extreme Weather Events and COVID-19: A First Look at the Number of People Affected by Intersecting Disasters	(IFRC & RCCC 2020)	53
Climate Smart Disaster Risk Management Programming during the COVID-19 Pandemic	(IFRC 2021)	41
COVID-19 Global Risk Communication and Community Engagement Strategy—Interim Guidance	(GOARN, IFRC, UNICEF & WHO 2021)	77
Transparency—Why it Matters at Times of Crisis	(WTO 2020)	4
Improving Trade Data for Products Essential to Fight COVID-19: A Possible Way Forward	(WTO 2021)	73
COVID-19 Crisis and Support for Agrifood: Public Sector Responses Through the Financial Sector	(FAO 2020)	2
Policy Brief: Are we there yet? The transition from response to recovery from the COVID-19 pandemic	CODATA, IRDR, RADI CAS & Tonkin+Taylor International 2020	9
RDA COVID-19 Recommendations and Guidelines for Data Sharing	(RDA 2020b)	2107
Enhancing Access to Research Data to Combat COVID-19: Recommendations to Funders	(RDA 2020c)	102
OECD Policy Responses to Coronavirus (COVID-19) Why Open Science is Critical to Combatting COVID-19	(OECD 2020)	56
Open Data in action: Initiatives During the Initial Stage of the COVID-19 Pandemic	(OECD 2021)	149
COVID-19 and Climate-Smart Health Care: Health Sector Opportunities for a Synergistic Response to the COVID-19 and Climate Crises	(CIF & WBG 2021)	13

1 WHO Coronavirus (COVID-19) Dashboard: https://covid19.who.int/.

2 DesInventar: https://www.desinventar.net/.

3 OCHA Financial Tracking Service Platform: https://pfdata.unocha.org.

Tackling the COVID-19 crisis also involves exploratory methodology and compound technical solutions for improved data literacy, enhanced data skills, consolidated data systems, and resilient crisis data operation and communication ('technology'). For example, diversified ways of data capture (i.e., passive, active, sentinel, and syndromic surveillance by the US CDC surveillance system, Congressional Research Service 2020) develop a better understanding of the health crisis. Enhanced interoperability across systems promotes inclusive exchange of local, traditional, and Indigenous knowledge, thus contributing to flourishing data ecosystems (WFP & UNECA 2021). The popularity of digital devices leads to the boom of telehealth, teleconference, online education, robotics, drones, 5G internet connection (World Economic Forum 2020), big data technology (Mao et al. 2021), artificial intelligence, cross-domain ICT tools, and others to support effective epidemic emergency management. 'Ethics' is also critical in guiding the operation of people, resources, and technology adoption to save losses. The legal, ethical, and responsible data sharing calls for ethical reviewing of research works, protection of indigenous people's rights and interests (The CARE Principle for Indigenous Data Governance), and ethical use of open data, licenses, and agreements in data acquisition (RDA 2020a & 2020b).

The delivery of COVID-19 information is expected to be 'credible, trusted, relevant, timely, accessible, and actionable' (WHO 2022) ('communication'). WHO-affiliated entities and member states are responsible for reliable data, information, and knowledge production and delivery transparently and timely to avoid confusion (WHO 2020d). 'Risk communication and community engagement' inventions are used to monitor the performance of communication and receive feedback through diverse communicative channels, such as social media and other digital ones. 'trust' (The Royal Society 2023) is built upon the lessons we learn through COVID-19. Other essentials also nourish trust. For example, we embrace the collaboration of the broadest masses of people to tackle COVID-19 under a secure information environment featuring trustworthy data, robust data systems, reliable data methods and technologies, swift and clear communication, efficient and FAIR operation of resources, and maintenance of the pandemic data lifecycle as well.

The COVID-19 pandemic showcased the systematic interrelationship between different crisis essentials. It involves the broadest masses of 'people,' with global collaboration becoming more popular than ever (Lee & Haupt 2021). Data-relevant research 'resources' once again proved their irreplaceable roles in the robust 'operation' of crisis (Xu et al. 2020), while 'technology' boosted crisis data work extensively. The utilitarian 'ethics' balanced the interests of different crisis data groups and maximized the public good. Prompt and unambiguous 'communication' followed to ensure appropriate data response while sustained 'trust' ensured efficient health crisis management throughout the full pandemic stages. These crisis data essentials worked systematically and consistently for health crisis management. Immaturity or insufficiency in these essentials would lead to vulnerabilities and risks.

4.2.2 Data in the Türkiye-Syria earthquake

On February 6, 2023, a 7.8 magnitude earthquake hit southeast Türkiye and north Syria. In Türkiye, the epicenter is within Pazarcık district at Kahramanmaraş province. On the same day, at 1:24 pm, another earthquake of magnitude 7.6 hit the same area at a different epicenter in Elbasan district. Both fault ruptures occurred on the East Anatolian Fault, one of the country's active fault lines. Earthquakes affected ten regional provinces in Türkiye, with three (Kahramanmaraş, Hatay, and Adıyaman) in the worst condition. According to the Disaster and Emergency Management Authority (AFAD) data, the death toll exceeds 50,000 deaths as of the end of August. It is believed that the real number was triple from what is officially recorded. More than 120,000 were injured, with almost two million refugees relocated to other parts of the country. Thousands of buildings in the area had collapsed, heavily or moderately damaged. The effects of the earthquake, both at economic and social dimensions, will take at least a few years to recover. However, in Syria, things are even worse. According to UNHCR's report (2023), 'at least 8.8 million people have been affected by the earthquake in the Syrian Arab Republic (Syria),' which led to 'compounding suffering in a country already devastated by 12 years of crisis.' Due to the availability of supporting materials, we focus mostly on the Turkish side for the 'PROTECT' analysis throughout process of earthquake disaster response.

Local 'People' are the main contributors to this hazard's preparedness, response, and recovery. They acted as the first responders, lifesavers, and data collectors. Especially in the first chaotic 72 hours, the most crucial time after an earthquake, the local people had to respond to save as many lives as possible. There was a strong solidarity among the whole nation. Volunteers rushed to the earthquake region, a large area consisting of the 11 affected provinces. Local citizens took the predominant role in data resources ('resources' on data) capture, usage, and sharing for reuse. They used mobile phones to ask for help if someone was under the rubble, identify the rubble's location, explain the condition, and contact family, friends, and colleagues. Due to the damage to the communication infrastructure, data systems ('resources' on data systems) did not work properly in the initial days. Again, people, such as computer engineering students, developed a mapping tool that was immediately used to support search and rescue, aid delivery, and logistics operations. However, no specific emergency funding was available to find, reach, and generate data ('resources' on crisis data funding). Therefore, clean and trustworthy data did not arrive for timely response ('operation'). All the data available was messy, needed to be corrected, and hard to understand and judge. Luckily enough, cutting-edge technologies ('technology') still found their way to boost data work, such as drone technology adoption to gather damage and loss data and artificial intelligence (Goksu & Kamiloglu 2023) for hazard control and decision-making. Nonetheless, no data ethical issues have been addressed during this emergency ('ethics'). Most of the social communication ('communication') was through WhatsApp groups and messages, which means more powerful communicative ways are needed, especially for authority information dissemination. It was very hard to sustain trust either during the earthquake or at present when several months have passed ('trust').

This case exposed the deficiency of data essentials in a hazard. Although 'people' were gathered to rescue residents, there was not enough attention to the threatened data. The lack of sufficient data preparedness ('resources') brought side effects, leading to ineffective crisis 'operation,' limited exploitation of digital 'technologies,' inadequate authorized 'communication,' and the absence of mutual 'trust' mechanisms, which in turn drew back the emergency recovery rate of the entire crisis ecosystem. Obviously, this case also demonstrates that 'resources' predominately drive resilient crisis data work. It motivates 'people' to collaborate, supports the unique operation of crisis data work in tailored scenarios, revokes full exploitation of digital technologies, and provides the soil for utilitarian ethics and prompt communication, thus nourishing fully trustworthy ecosystems. However, data never comes alone but works with other essentials. Different scenarios featuring various risks may heavily rely on the preparedness of different essentials. Inadequate preparation of certain essentials might lead to the inefficiency of other essentials.

4.3 OPEN SCIENCE MAPPING FOR FUTURE ENVISION

Open Science opens frontiers for future science and society in which crisis data management cannot be neglected. Following the *UNESCO Recommendation on Open Science (2021)*, we see 'resources' mostly represent 'open scientific knowledge,' highlighting crisis data and systems. 'technology' lies in 'open science infrastructure,' pinpointing the utility of high-tech driven science for emergencies. 'Open engagement of societal actors' may find their way into 'people,' 'ethics,' and 'trust,' while 'communication' goes to 'open dialogue with other knowledge systems.' This way, the four pillars of Open Science have been neatly mapped into our 'PROTECT' essentials.

As for implementation, prepared resources and promising technologies call for transparency, scrutiny, critique, and reproducibility. Utilitarian data ethics goes for equality of opportunities. United people and prompt, clear communication will assume crisis management responsibility while emphasizing respect, accountability, collaboration, participation, and inclusion in crises. Furthermore, the unique operation of crisis highlights flexibility while trust stands for the sustained future.

5 DISCUSSION AND CONCLUSION

The adoption in these two cases further validates the feasibility of the 'PROTECT' essentials. The rapid assembly of potential stakeholders became the most powerful driver in the two crises. However, lessons were also learned from the crisis data work. In the case of COVID-19, the UN, universities, and research institutions actively captured and managed large-scale dynamic data, providing huge potential opportunities for timely global crisis operation and communication.

This helped to co-build a trusted ecosystem to fight against the global health crisis. However, the disaster loss in Turkey's case due to insufficient data preparedness significantly negatively affected the region's response and recovery. The lack of sufficient data hindered effective data governance and undermined the use of STI tools and others. Based on these discussions and the analysis of the 'PROTECT' framework, we proposed several suggestions for future work.

United people and prepared resources are prerequisites for resilient disaster risk reduction. When confronted with disasters, the consistency of common actions among diverse interest groups and the richness and preparedness of data-relevant resources serves as the primary driving force for disaster governance. The stakeholder approach ensures that no one is left behind in resilient disaster risk reduction before, during, and after any crisis scenarios of data decisions and actions, such as data preparation. The preparedness of data and supporting funding further consolidate disaster risk reduction through data-driven research, monitoring, and decision support.

Harmonizing cutting-edge STI adoption and fair ethics are essential for resilient disaster risk reduction. The STI adoption brings great potential to break data silos, thus narrowing down data gaps. For example, the advancements in network technology, big data, cloud computing, blockchain, and other cutting-edge adoptions have become the most important accelerators for crisis data work. These works should follow utilitarian ethics to ensure maximized benefits for all, thus facilitating the efficiency of the overall crisis data work.

Unique operation and prompt, accurate communication effectively amplify data's powerfulness. As addressed previously, the unique operation of crisis work in tailored scenarios is essential to fully exploit data value. Data challenges may vary by scenario. Then, agile operation of lifecycle data in crisis should address different essentials in need, thus making the crisis data under an on-demand model. Prompt and unambiguous communication between professionals and citizens across domains and regions will extend the capacities of crisis data operation, thus boosting disaster mitigation in the long run.

Co-development of a trustworthy crisis data ecosystem proliferate Open Science. With multiple involvements, enriched preparedness of data-relevant resources, trustworthiness consolidates the entire crisis management cycle by establishing a solid foundation for crisis data management, boosted by STI adoption in strict accordance with fair ethics, unique operation of data work in tailored scenarios, prompt communication, and others. Furthermore, trust extends the resilience of the crisis ecosystem through mutual understanding and unified efforts in the face of uncertainties. Successfully mapping into the Open Science landscape does not imply the default open-science way of working for the PROTECT essentials. The values of 'quality and integrity, collective benefits, equity, and fairness, diversity and inclusiveness' (UNESCO 2021) should always be readily shared to ensure better-prepared crisis data work for a sustainable future.

Finally, this research introduces the 'PROTECT' essentials as a checklist for crisis data policies and the 'Ups' guidance for implementation, followed by case studies for lightweight validation. The survey shows great potential in data-driven crisis management and gaps to be bridged for future crisis management. Any usage of these 'PROTECT' elements should consider tailored crisis scenarios, and the importance of different essentials may vary due to circumstances. Future studies will explore quantitative research methods in detailed scenarios to flesh out the 'PROTECT' framework better.

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COMPETING INTERESTS

The authors have no competing interests to declare.

AUTHOR CONTRIBUTIONS

Professor Virginia Murray and Mr. Francis P. Crawley jointly launched the 'Data Policy for Open Science in Crisis' session during the EOSC Symposium 2022. Dr. Lili Zhang proposed the 'PROTECT' framework and drafted the paper based on her talk during this session. All co-authors reviewed and revised the paper, among which Professor Perihan Elif Ekmekci further elaborated on 'ethics,' Professor Virginia Murray guided international-level crisis data policies study while Mr. Francis P. Crawley introduced 'trust.' Professor Burcak Basbug conducted the case study of the February 6, 2023, Türkiye-Syria earthquake. Ms. Xueting Li and Ms. Yandi Li provided facts for worldwide crisis data policies and literature review.

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