5-11-2023

WHAT IS THE ROLE OF INFORMATION AND COMMUNICATION TECHNOLOGIES (ICT) IN BUILDING RESILIENCE ASPECTS IN CASE OF DISASTER?

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WHAT IS THE ROLE OF INFORMATION AND COMMUNICATION TECHNOLOGIES (ICT) IN BUILDING RESILIENCE ASPECTS IN CASE OF DISASTER?

Research Paper

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Abstract

Due to climate change, hazardous events and disasters are going to become more frequent and intense, increasing disaster risk. Information Communication Technologies (ICT) can play a powerful role in building resilience in all the phases of the disaster cycle by stimulating collaboration and communication among different actors. However, there is a lack of studies that connect these fields of study. Thus, a resilient thinking approach that considers ICT and disaster is required to face these challenges. To identify resilience aspects promoted by ICT in case of disaster, this study conducted a content and bibliometric analysis, resulting in nineteen aspects. The findings contribute to the current discussion and help decision-makers in understanding how to implement an ICT that enhances resilience for communities affected by disasters.

Keywords: Resilience building, Disaster Risk Reduction, ICT.

1 Introduction

The impacts of climate change will affect society in various ways by altering our environment and climate, transforming extreme events into an everyday reality (IPCC, 2021). Hazardous events will become more intense and frequent, increasing disaster risk (UNDRR, 2020), therefore connecting the disaster and climate approaches on the bases of adaptation and resilience need to place at the forefront of the discussion. Resilience is essential for the future survival of all the systems (UNDRR, 2017b) and can support the prevention of crises, enabling a more sustainable society in the long term (UNDRR, 2020; Sakurai, 2020). Research indicates that hazards do not affect people equally, due to inequalities and vulnerabilities present before a disaster, affecting the most vulnerable and excluded groups (Masiero, Nielsen, 2021; UNDRR, 2020). Thus, studies for policy planning, resilience building and the enablement of better decision-making for all the phases of a disaster are urgent due to environmental changes, imminent disasters and pre-existing vulnerabilities and inequalities.

The concern with this topic by the international community is present in the Sendai Framework for Disaster Risk Reduction (DRR), published in 2015 and adopted by the UN in accordance with the 2030 Agenda of the Sustainable Development Goals (SDG), focusing on being action oriented. This Framework changed the paradigm of the disaster risk reduction approach from a "culture of response" to a "culture of prevention" (Zuccaro, 2020). The year of 2022 was the halfway point of the agreement, and although some goals were partially achieved, the COVID-19 pandemic retreated advances (GAR, 2022), thus post pandemic resilience built is essential.

This study focused on the post-Disaster phase, there are three main stages of a disaster, each has its own components, resulting in six phases of a disaster, all of them represent the DRR or Disaster Management

(DM) practices. The policies developed to achieve all the DRR phases' demands social and economic changes aiming at resilience building and risk reduction measures. The three stages are pre-Disaster, during the disaster, and post-Disaster. The first involves monitoring practices for risk reduction and mitigation; the second aims to reduce the damages; and the third on recovery and reconstruction of losses.

Information Communication Technology (ICT) practices can promote new agency to people affected, assess the most vulnerable and help achieve Disaster Risk Reduction and Disaster Management practices (UNDRR, 2020; UNDRR, 2017b; Mohan, 2020). However, the field of ICT and resilience in disaster context is limited with frameworks and empirical investigation, especially the phase of post-disaster and building adaptation (Heeks and Ospina, 2019).

This work aims to identify and analyse aspects of building resilience through ICT practices in case of post-disaster, by the presence of ICT in enabling those. This study is limited to the information system literature. The research question that guides this study is:

RQ: *What is the role of ICT in building resilience capabilities in a post-disaster context? What are the main aspects on this process?*

A systematization of articles about post-disaster, ICT and resilience was conducted to identify the key aspects of resilience, through a bibliometric analysis and a content analysis of 12 articles. This paper provides an important contribution to the research field of ICT and disaster risk reduction by identifying key aspects for the future development of resilience frameworks for scholars as well as policymakers and decision-makers in the field who are interested in understanding how to implement an ICT that enhance resilience for communities affected by disasters. There are five main sections: 1. Introduction, 2. Methodology, 3. Literature Review, 4. Results and conclusion. The first part is an explanation of the objectives and focus of the article. The second part discusses the methodology. The third comprehends the bibliometric review and literature review of the main concepts that relate Disaster and the ICT field of study and the main aspects of ICT and resilience in a disaster context. The fourth part, analysed papers, the resilience aspects, and its application on a framework, as well sums up the main analysis, proposes paths for further research, and conclusion of the analysis.

2 Research Method

To understand the role of ICT on building resilience in a context of post-disaster and the resilience aspects involved, a literature review was conducted. This review is divided into three parts: 1) a bibliometric analysis to map the main topics that they are related and emerging trends in the field of ICT and disaster; 2) review of reviewed literature articles, to understand main aspects of ICT and resilience and ICT and disaster field; and 3) review and content analysis of 12 articles that presents a description of cases in which ICT were used in the post-disaster context.

The aim of the bibliometric analysis is to uncover emerging trends in the field of study through a science map approach. According to Donthu et.al (2021), this method is useful for mapping massive scientific knowledge and making sense of large volumes of data, specifically with broad research questions, enabling to identify knowledge gaps and present novel ideas for investigation. The co-word analysis is one of the science map techniques that was used in this research to examine the content of the publications. By using the "author keyword" column, which contains the keywords that synthesizes the article and are selected by the authors, it was possible to identify main topics, this approach assumes that words that frequently appear together have a thematic relationship with one another. The R software was used, specifically, the package bibliometrix, which has functions for this analysis. The second part of the analysis helps to build a context comprehension of the field by synthesis of literature reviews papers on ICT and Disaster and ICT and resilience, as well in establishing initial codes for the thematic analysis.

The analysis of the 12 papers were conducted through and conceptual analysis using the qualitative software, Atlas.Ti. The conceptual analysis is a useful method for framework development, in which the following questions are present in the analysis: 1) general theme, 2) field of knowledge, 3) result, 4)

concepts and meaning. The outcome of this process are several codes that are future related in broad categories in a second level of coding.

Both selections of articles as the bibliometric analysis use the same dataset, which was collected through keywords on Scopus database of articles. The Scopus database was chosen due to the possibility to export the research into a BibTeX file, enabling the analysis in a bibliometric perspective. Other databases were considered such as WoS and Science Direct initially, however, the lack of possibility to extract the research as datasets made it impairable. To comprehend the field of study, the following search string was applied on the title, abstract and keywords: ((ICT OR "Information Technology" OR "Tecnologia" OR TIC OR "Sistemas de Informa*" OR "knowledge management" OR "gestão do conhecimento") AND ("Disaster" OR desastre)). The filtering criteria for the research were: research articles or review articles in Portuguese, Spanish, or English from 1980 till 2022, resulting in 1194 articles. The choice of keywords and database might exclude many studies related with the research field, by using other terms and indexes, however the different analysis on the theme and coverage of the review for post-disaster context bring a practical and meaningful sample of relevant research.

3 Literature review

3.1 Bibliometric Analysis

The bibliometric analysis aimed to understand emerging trends in the ICT and disaster research field, as well to identify the scientific production until 2022. Therefore, an analysis of the collected articles from the Scopus database was conducted using the bibliometrix package from the R software. The database is composed of 1194 documents from 1980 to 2022 from 744 different sources.

Ten core authors were identified, by quantity of published research on the topic and H-index: Sood K., Zhang Y., Wang J., Beydoun G., Dorasamy M., Li X., Raman M., Wu Y., Zhang L., Leelawat N. and Li J. Some authors relate by co-authorship (Wu Y., Li X. and Zhang L, Zhang Y, Li J.; and Raman and Dorasamy). Selected studies by these authors were used on this research literature review for developing a context of the ICT and disaster field. To understand core themes on the field it was used a conceptual analysis and thematic evolution, the indicators which measure this are centrality and density, the first measure the relevance of the theme and the second its development on the field. Two analyses were combined, one by authors keywords and the other by title bigram keyword, the software identified clusters and their volume of production overtime to map the main topics from 1980 to 2022.

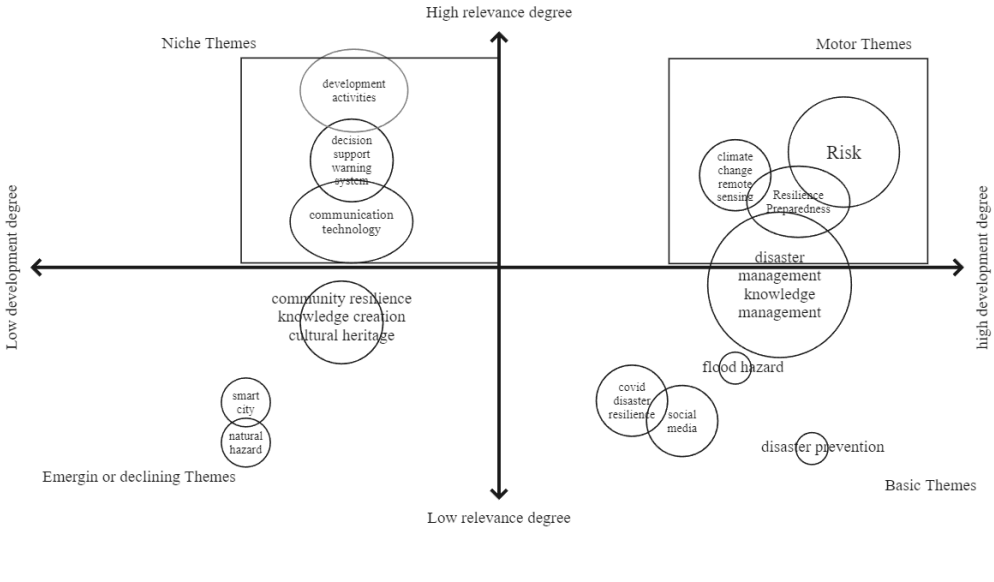

Figure 1. Thematic Concept Map of ICT and Disaster Field

The proximity between groups correspond to a proportion of articles on which they are present together, therefore "risk", "resilience" and knowledge management appear close due their relation on a large portion of articles. Its relevant that "resilience" only start appearing on the map by 2015 as an emerging trend, achieving a space of a motor theme in 2022, showing its relevance for the theme on the relation of risk and a field to be studied. Emerging trends is another relevant aspect, in which knowledge creation and community resilience is set as a emerging theme for the field when comparing the theme across years. Other important aspects are new technologies emerging in the field such as machine learning, internet of things, cloud computing, internet of things, early warning systems, cyber security, GIS, social media, and the increase of importance in knowledge management studies from 2012 to 2020.

Through a lexical analysis, using the dictionary method, a set of keywords were selected for each disaster phase. Measuring how many articles cite at least one of the keywords, and which one document can discuss more than one disaster phase or not specify none in the abstract, for this reason there is no total count of documents, since each phase was composed by specific keywords, it allows to understand the academic scenario: Pre-Disaster (289), Prevention (86), Mitigation (83), Preparedness (120), During-Disaster (337); Response (273); Post-Disaster (257); Recovery (183); Reconstruction (23); Rehabilitation (9). Most of the research in the field is focused on measures during the disaster or just after it occurs, studies on the long-term phases such as preparation, reconstruction are the ones with lack of research.

3.2 Defining disaster and resilience

In this research the concept of disaster is understood as consequences of an event or a series of events, whether man-made or by natural hazards, that unleashes several damages, disrupting communities and leading to losses and impacts (Zuccaro, 2020; UN, 2016). What will determine its severity are the previous social and economic scenario due to the degree of exposure to risk and capacity of reaction (FGV, 2019). It's important to emphasize that natural hazards and man-made hazards are considered events and not the cause of the disasters, the human action, or lack of it, that turns these events into disasters. A common sense is that disaster happens by exogenous factors, such extreme events, but this vision is apolitical and ahistorical, not taking in consideration how vulnerabilities were produced, leading to apolitical solutions (Sou, 2021)

Therefore, humans play a central role in creating disasters by creating new risks due climate change, constructing from social processes the scenario of vulnerability and poverty and by practices or non-practices on preparedness (Smith, 2006; GAR, 2022; ReliefWeb, 2021). Some of the factors presented highlight the complexity of disasters, a wicked problem on which risk must be understood as systemic, since the different variables and dimensions - hazard, exposure, and vulnerability - are interconnected and influencing each other. Human responsibility on this scenario is partially address in reducing disaster risk and building resilience, since if risk is reduced, resilience increase, as set by the Sendai Framework goals, therefore, since risk is understood as systemic, the same fits for resilience.

Resilience is commonly understood as "the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions" (UN, 2016a). The concept is considered limited due it proposes to return to the original conditions, the same that was unable to deal with shocks and long-term stress (Sakurai, 2020).

Expanding the concept above, it will also be used the Build Back Better (BBB) approach, which acts on the post-disaster phases (recovery, rehabilitation, and reconstruction) aiming to integrate Disaster Risk Reduction to restoration of infrastructure and societal systems to revitalize livelihoods, economies, and environment (UNDRR 2017a), therefore reducing risks and vulnerabilities to future disaster and build community resilience (UNDRR, 2017a). The BBB aims to go beyond a bounce back scenario, building resilience in manners to improve previous conditions.

Some scholars also relate resilience with resistance, on which communities deny the status quo that led the situation of disaster. Understanding context is important for resilience building and changing the system that led to the severity of the impact, also this concept highlights the importance of community's action on more than just coping but refusing the status quo and putting them as an active part of their future construction and resilience building (Sou, 2021).

In a nutshell, disasters happen due human action or inaction and resilience building is a form to address this by reducing risk and improving previous social context. The next parts will understand the role of ICT on this concepts and what its role in building resilience.

3.3 How is ICT set on Disaster Reduction?

Although some hazards are unavoidable, through resilience their impact are diminished and can be minimized. ICT can play powerful role in this effort, it can be applied in all the phases of the disaster cycle, and stimulate collaboration and communication among different actors, enable easier alignment in processes and outcomes in disaster management (DM) and help planning and implement risk reduction practices (Mohan, 2020; Sood, 2021). A panel of experts in Mohan's (2020) study concluded that effective ICT could play the role of a catalyst in all the three cornerstones of sustainable development and risk reduction: social inclusion, economic development, and environmental protection. Sood (2021) identified some of the main ICT uses on DRR and the emerging trends on the field, they were Internet of things (IoT), cloud computing, big data, data mining, social media, artificial intelligence, machine learning and sensor network. These technologies although its different uses are connected by the same aspects, knowledge management, production, and circulation (Mohan, 2020). They can enable assessment on potential risks, damages, and power to respond to a disaster, through simulations and forecasts, depicting trends and dynamics for better policy planning for prevention, therefore playing a central role for achieving the Sendai Framework "culture of prevention" (Zuccaro, 2020; Oktari, 2020; Atta-ur, 2019). Although the different types of knowledge management (Oktari, 2020), this article will focus on technologically oriented knowledge management (KM) which enables individuals to support themselves for collaboration and communication. In addition, technological artifacts are primary driver of knowledge acquisition, creation and sharing, supporting the collaboration of stakeholders for more sustainable and effective decisions and policies (Oktari, 2020).

Some ICT practices, which focus on knowledge system and data management, are already in use for disasters (Sigma Database, NatCatService, EMDAT, and DesInventar), they are an example of valuable management tools and forms of knowledge management for disaster management. Datasets can allow analysis of disasters causes and consequences, fostering actionable knowledge, decision-making, and helping increase common information, and communication among stakeholders (Muñoz, 2017, Oktari, 2020).

For the effective use of dataset as decision tools, to characterize, assess, and evaluate the hazards, vulnerabilities, social and geographical conditions for risk reduction, mitigation measures or recovery response, some important aspects need to be considered. Despite our society is immerse in data, being considered a datafied society (Masiero and Nielsen, 2021), the COVID-19 pandemic demonstrates that still people from the margins are not represented in data or do not have the access to the ICT artifacts, therefore, ICT can continue to reproduce socio-economic inequities if data justice aspects are not considered. For example, in a case presented by Taylor (2017) the processes of the system were excluding the poor who did not have access to a phone, internet or/and lack of knowledge on technology. It also points out that ultra-poor were transformed into consumers using the database. To sum up, the system amplified inequalities since for richer citizens it was easier to use and access the services. Another aspect is the amount of data in the datafied society can have negative effects, according to Pan and Zhang (2020) the COVID-19 created an infodemic, making it difficult for people to discriminate the reliable sources and information. Big data and the overwhelming amount of information available is still limited and not effective in the use and translation of this into knowledge and furthermore into decision making for end-users (Zuccaro, 2020, Sakurai, 2020). On times of crisis, infodemic have

aggravating aspect since the need accurate information in a short time span for decision-making. In addition, the amount of data and its quality for knowledge translation (relevant, usable, legitimate, and credible data) and respecting issues of privacy are one of the key issues debated in the ICT practices for disaster management and disaster risk reduction. A way to reduce those aspect are the development of a holistic approach that integrates different data ecosystems and sources from different stakeholders, orchestrating information and checking accuracy and contextualizing data with regional or local datasets for better assessment of risks and impacts (Pan and Zhang, 2020; Li, 2019).

Although data is relevant for decision processes, it does not guarantee action to change and can carry negative impacts since ICT artifacts are part of socio material processes and can reproduce, transform, adapt, or reinvent daily social practices or be reinvented by them (Porto, 2021; Pozzebon and Diniz, 2012). An example of the data issues was the practices of ICT to deal with the COVID-19 pandemic, posing a question about the quality of data for decision-making and if the monitoring tools developed, were becoming totalitarian surveillance tools (Diniz, 2020). Despite negative ICT cases during the COVID-19 outbreak, some showed how ICT in periods of crisis and extreme events could help policymakers and citizens in monitoring, planning, and communicating policies for resilience. The fast changes that needed to be made to slow down the virus.

Some factors affect this social process on accepting the ICT for DRM, being key elements to help building resilience through ICT, Meechang et al (2019) identified five potential factors: perceived usefulness (PU), Perceived East of Use (PEOU), Information Accessibility (IA), Social Influence (SI) and Disaster Knowledge (DK), also other secondary factors were identified experience, trust, awareness, and demographics. The PU was identified as the most important factor, SI was relevant specially on local communities and IA on helping to perceive risks.

The studies which relate ICT and Disaster presented do not describe the concept of resilience used, therefore, its necessary to understand how the field of ICT conceptualize resilience. Heeks and Ospina (2019) on their review identified that the field uses resilience as a concept for short term responses, not bouncing forward for adaptation, and on three main uses: 1) Resilience of an information system input system (RISIS), mainly human system affecting IS implementation; 2) Resilience of an information system (RIS); 3) Resilience of an information system outcome system (RISOS). The authors claimed for the understanding of resilience as systemic, adding longer-term practices, therefore understanding resilience as "a way to avoid the perpetuation of systemic inequalities" (Heeks and Ospina, 2019).

As set by the authors, the field of ICT lacks concepts on resilience, therefore the authors deepened the concept by a wider resilience literature on other fields of research, proposing a framework for the field. The attributes aim to enable an ICT artifact to bounce forward or return unaffected by a shock, are: (i) Robustness, the ability to maintain its characteristics and performance, related with infrastructure and governance; (ii) Self-organization, ability to recover and rearrange its functions and processes, related with collaboration and local leadership; (iii) Learning, ability to generate feedback, as capacity building; (iv) Redundancy, ability to maintained even during crisis, to guarantee resources; (v) Rapidity, as time to access and mobilize resources in a timely manner, essential for saving lives; (vi) Scale, access to resources and structures outside the immediate system; (vii) Diversity and Flexibility, variety of assets (including knowledge), for adaptable decision-making; and (viii) Equality, in terms of equal access to rights, resources and opportunities for stakeholders

Other concept of resilience on the field of ICT, specific in context of crisis, is e-resilience, which defines as the ability of ICT infrastructure system to withstand, recover from, and change in the face of external disturbance, promoting societal resilience (Zohard, 2022). A resilient infrastructure is essential for a fastest and better restoration process, for example due to the infrastructure needed to guarantee communication during and after a disaster (Sakurai, 2020). E-resilience is a strong concept used in Asia-Pacific Information Superhighway (AP-IS), and promoted through policies, since its potential to reduce disaster risks and improve disaster management. Understanding and measuring the components of e-resilience can enhance the success of disaster risk management as the practices and targets combine ICT and DRR indicators. The concept is structure in the following pillars (Zohard, 2022): (i) ICT infrastructure; ICT policy; (ii) New systems and applications; (iii) Digital data; and (iv) Hazard and

exposure. The concept highlights the relevance of infrastructure in ICT to enhance resilience in case of disasters, considering not only technological aspects but also all, the social practices that involves the artifact.

As demonstrated, there is a gap in data collection, generation and distribution of information that can be diminished with the collaboration of different stakeholders. Porto (2021) developed a framework for data sustainability transformation, on which the participation of stakeholders on different scales the macro (international/national), meso (city governments) and micro (communities, local NGO, and other grassroots organizations) level are fundamental for data-enabled sustainability. Therefore, it should consider bottom-up and top-down narratives with big data and citizen participation processes, the flow of data between different actors enable coordination and communication from disconnected actors. Creating data exchange among different stakeholders promotes the creation of communication channels, engendering diversity of perception, empowerment of invisible groups, community resilience and social learning (Porto, 2021). This concerned is also present in Li (2019) research, on which citizen participation presents as a path for new kind of data infrastructure, connectivity, and collaboration, as well to identify the "true" effectiveness of an ICT implementation by understanding resilience through the community point of view and being able to reduce colonial views (Andoh-Baidoo, 2017).

Citizen Science present in this way as a form to collect data with the participation of society. The concept has several meanings and is a concept in debate; however, for this study the concept of Fraisl et al (2019) will be used: "public participation", "voluntary contributions", "knowledge production". This method of data collection enables a participation of the population in policies, promoting empowerment, and visibility of vulnerable people, respecting the UN "Leaving No One Behind" (LNOB) presented in the 2030 agenda.

The concepts on this section provided an initial conceptualisation of main aspects of ICT and resilience (Table 1), which will be considered on the case analysis. The specific research of ICT on post-disasters scenarios provides the identification of other aspects and their relation.

Uses of ICT on Disasters	ICT aspects to build resilience	ICT role/effect
Knowledge management Knowledge production Knowledge sharing	Citizen Science Contextualization Data integration Diversity Equal information access Good quality data ICT costs of access Learning Local knowledge Rapidity Robustness Redundancy Scale Self-organization Stakeholder cooperation Stakeholder participation Strong community bonds Tech infrastructure	Assessment of potential risks and damages Collaboration Communication Easier alignment Legitimacy Planning Stakeholder cooperation Stakeholder participation Strong community bonds

Table 1. Main concepts of ICT and Disaster resilience identified.

3.4 Aspects of Resilience on ICT

To develop a framework for ICT resilience in a disaster scenario two process for filtering was conducted, the first by a lexical dictionary method, using keywords to identify in the abstract post-Disaster

documents. Second by reading each abstract using a criterion of inclusion and exclusion: 1) inclusion if the research presents an analysis or case study of ICT, disaster, and resilience focusing on the local level (government, communities); 2) exclusion: unavailable pdf document or do not present the inclusion characteristics.

The conceptual method was used to identify in each document the main concepts, disaster phase, type of ICT, and results. First a coding process was developed, using the identified aspect of the literature review. A second level coding was required to organize in broad concepts and aspects of resilience, one way of developing these aspects were by analysing the results of the ICTs and what led to a positive of negative result. The analysis of the articles and codification resulted in the following aspects of resilience: Citizen Science (5), Contextualization (5), Cultural aspects (5), Data diversity (3), Data integration (2), Equal information (9), Good quality data (4), ICT costs of access (2), Learning (2), Rapidity (2), Robustness (4), Redundancy (3), Scale (4), Self-organization (4), Stakeholder cooperation (3), Stakeholder participation (8), Strong Community bonds (2), Tech infrastructure (7). Those aspects are described on Table 2.

ASPECTS	DESCRIPTION
Citizen Science	Production and/or dissemination of data with the participation of society ("public participation", "voluntary contributions", "knowledge production") (Fraisl et al, 2019, Tasic, 2016).
Contextualization	Contextualizing the technology by its social context and using data with regional or local datasets for better assessment of risks and impacts (Pan and Zhang, 2020; Li, 2019).
Cultural aspects	Collective common beliefs and values of a location that might influence the technology implementation (Andoh-Baidoo, 2017, Tasic, 2016)
Data integration	Orchestrating information of different sources and checking accuracy and contextualizing data with regional or local datasets (Pan and Zhang, 2020; Li, 2019).
Diversity	Variety of assets (including knowledge), for adaptable decision-making (Heeks and Ospina, 2019)
Equality	Equal access to information, rights, resources, and opportunities for stakeholders (Heeks and Ospina, 2019)
Good quality data	Quality of data for knowledge translation (relevant, usable, legitimate, and credible data).
ICT costs of access	Aspect related with the costs in accessing technology, mainly related with inequality
Learning	Ability to generate feedback, as capacity building (Heeks and Ospina, 2019).
Local knowledge	Participation of local knowledge on the implementation of the technology (Nakanishi, 2018).
Rapidity	Time to access and mobilize resources in a timely manner (Heeks and Ospina, 2019)
Redundancy	Ability to maintained even during crisis, to guarantee resources (Heeks and Ospina, 2019)
Robustness	Ability to maintain its characteristics and performance, related with infrastructure and governance (Heeks and Ospina, 2019)
Scale	Access to resources and structures outside the immediate system (Heeks and Ospina, 2019)
Self-organization	Ability to recover and rearrange its functions and processes, related with collaboration and local leadership (Heeks and Ospina, 2019)
Stakeholder cooperation	Ability and/or action of different stakeholders cooperate on data collection, production, dissemination and/or sharing of information,

Stakeholder participation	Ability and/or action of different stakeholders be part of the decision making or assessment process related with the technology
Strong community bonds	Ability of a community of communication and support
Tech infrastructure	Foundation upon which everything else related to ICT is built (Zohard, 2022)

Table 2. Description of aspects for a resilient capacity building using ICT.

Most of the studies had a bounce back perspective of resilience. The documents were more focused on the response phase, with none in the rehabilitation phase, also all refer to natural disasters. The information aspect was the most important related to the ICT field, specifically web-based information sharing systems, GIS, Monitoring platforms, and social media. The resilience aspect appears in the articles to prepare for futures disasters, therefore related with preparedness phase. Only one article presented a resilience framework, although it does not relate with the Sendai or SDG indicators. The table below summarizes the findings.

Author (s)	**Year**	**DM Phase**	**ICT and Disaster**	**ICT Uses**	**Key aspects of ICT and resilience**	**Analysis**
HIGASHIDA et al.	2010	Preparedness Response Recovery	Sensors Cloud computing	Knowledge management Knowledge production Knowledge sharing	Citizen Science Diversity Equality Learning Rapidity Redundancy Robustness Self-organization Stakeholder cooperation Strong community bonds Tech infrastructure Stakeholder participation	Presents the state of art of ICT usage in disaster resilience in Japan. The information aspect is relevant.
NAKACHI et al.	2015	Response Recovery	Simulation	Knowledge management Knowledge sharing	Equality Tech infrastructure	Study analyze how technology can be more resilient in case of disaster, not how can help enhance resilience for communities directly, although some aspects are present.
RESNYANSKY	2015	Response	Social Media	Knowledge management	Contextualization	A critical analysis on the use of social

				Knowledge sharing	Cultural aspects Equality Good Quality Data Local Knowledge	media in disaster scenarios.
TASIC et al.	2016	Response	Communication Tech Social Media	Knowledge management Knowledge production Knowledge sharing	Citizen Science Data integration Equality Learning Local knowledge Self-Organization Stakeholder cooperation Stakeholder participation Strong community bonds Tech infrastructure	Analyze the effectiveness of a technology in a disaster situation comparing two disasters (before and after the artifact). It focusses on the grassroot initiative. The results showed the ICT helped enhance resilience with a fast response and better distribution of aids and resources.
ARNESON et al.	2017	Recovery Response	Communication Tech	Knowledge management Knowledge production Knowledge sharing	Citizen Science Equality Good quality data Robustness Stakeholder cooperation Stakeholder participation	Examine the effectiveness of information structures after a disaster scenario in the US. The scenario presented the lack of the ICT-resilience aspects.
ARAKI	2018	Recovery Response	Communication Tech	Knowledge management Knowledge sharing	Diversity Equality Rapidity Robustness Redundancy Scale Tech infrastructure	Presents the state of art of ICT usage in disaster resilience in Japan. The information aspect is relevant.
NAKANISHI et.al	2018	Response	Communication Tech	Knowledge management Knowledge production	Citizen Science Data integration Diversity Redundancy Self-organization	Study aims to understand the role of implicit knowledge in a disaster management. ICT appears as part of the study in the possibilities to enable

					Stakeholder participation	communication and connection.
KHAN et al.	2019	Response	Monitoring hazards and aid	Knowledge management	Data integration Good quality data Stakeholder cooperation	Study focuses on the use of ICT for monitoring aid donations for transparency, more focused on the doners perspective.
ALI et al.	2020	Recovery Reconstruction	Monitoring	Knowledge management Knowledge production Knowledge sharing	Citizen Science Contextualization Cultural aspects Good quality data Stakeholder participation	Study aims to examine the effectiveness of practices in a post disaster phase. ICT is not the focus although is one part of the study. Some relevant aspects of ICT for resilience are described, with a focus on information
MULDER	2020	During Response Recovery	Communication tech Mapping hazards (GIS)	Knowledge management Knowledge production Knowledge sharing	Citizen Science Contextualization Cultural aspects Equality Good quality data ICT costs of access Robustness Self-organization Stakeholder participation Tech infrastructure	Analyze into a social justice and data justice perspective civic technologies created for disaster in the case of Nepal. One key aspect is the lens of vulnerability, how no tech is neutral, and the pre-existing conditions should be considered.
RUSSPATRICK	2021	During	Monitoring Communication Tech	Knowledge sharing	Contextualization Cultural aspects Equality Stakeholder participation Tech infrastructure	The research presents the case of the free and open source District Health Information System 2 (DHIS2) on Sri Lanka and Sierra Leone during the outbreak of Covid-19 demonstrated that for an artifact to be effective in case of shocks and crisis, building resilience, it is important to

						consider not only the artifact itself, but practices evolving it (Russpatrick, et.al 2021)
DLAMINI et al.	2022	During	Communication Tech	Knowledge sharing	Contextualization Cultural aspects Equality ICT costs of access Stakeholder participation Tech infrastructure	The research presents the case of MOBISAM on South Africa, regarding education policies during Covid-19. IT highlights the need of pre-conditions for a resilience building using ICT (Diamini S, Turpin, Herlman, 2022)

Table 3. Literature review of aspects of ICT and resilience

To illustrate some of the categories, a few examples of the cases were explained. On the Higashid (2010) case, knowledge management and sharing were not enough, even with information sharing of evacuation due an imminent disaster, a low percentage of the population followed the government instructions. They identified that the content of the information was important, for example, informing characteristics of the disasters, as well who were the elderly people of the community who require assistance. Other aspect presented on that case is data integration, due the different government datasets, the authors proposed a cloud infrastructure to standardize disaster prevention tasks.

On the aspect of equal access, the research of Tasic (2016), presents that information was not reaching people who lived in remote areas. Therefore, equal access and knowledge sharing are related and are important for disaster risk reduction. Still on the aspect of equal access, Mulder (2020) research presents the importance of cultural and contextual aspects, since the creation of online aid spaces, even for people with internet access was only possible for English speakers to engage, being a barrier for most of the population.

Resnyansky (2015) research allowed to understand the importance of data quality, presenting how data noise on a disaster is prejudicial, on the case the noise was between local knowledge and government information for evacuation that was dissonant, therefore cultural and context aspects, as well the quality of the information played a central key on building resilience.

The aspect of resilience identified on the cases are linked to results of transparency, accountability, community empowerment, legitimacy, trust in information and leaving no one behind. Notably the communication among multiple stakeholders in a disaster context combined with local knowledge is a key aspect for resilience capabilities building.

4 Results and Conclusion

This study offers a starting point for identifying aspects of resilience promoted by ICT in a disaster context. This study is a proposal of a framework for undestand ICT and Disaster relation with resilience capabilities building, focusing on the ICT field. The analysis of literature and the 12 cases, allowed the identification of main aspects for resilience capabilities building on the ICT and Disaster field, as well the uses of ICT in context of disasters and its participation and practices that can lead to social effects.

The Figure 2 present this initial proposal of framework, on which is necessary to understand the previous context and social practices for ICT implementation, and once is implemented which social practices

were modified by ICT or how the ICT were modified by the previous social practices. Undestanding this scenario on which ICT is set and constructed, we can identify its uses on a disaster context, those can appear on different forms depeding of the goal of the techonology. A techology to be part of the development of resilience capabilites need to contain some of the aspects indenfied. The quantity and combination of aspects for each disaster phase, uses of ICT or type of technology needs to be further studied. With the implemenation of the aspects some effects might happen on the locality, for example on the cases with the Citizen Science aspect allowed stakeholder participation, communication, collaboration, better assessment of potential risks and damages and strengthened community bonds.

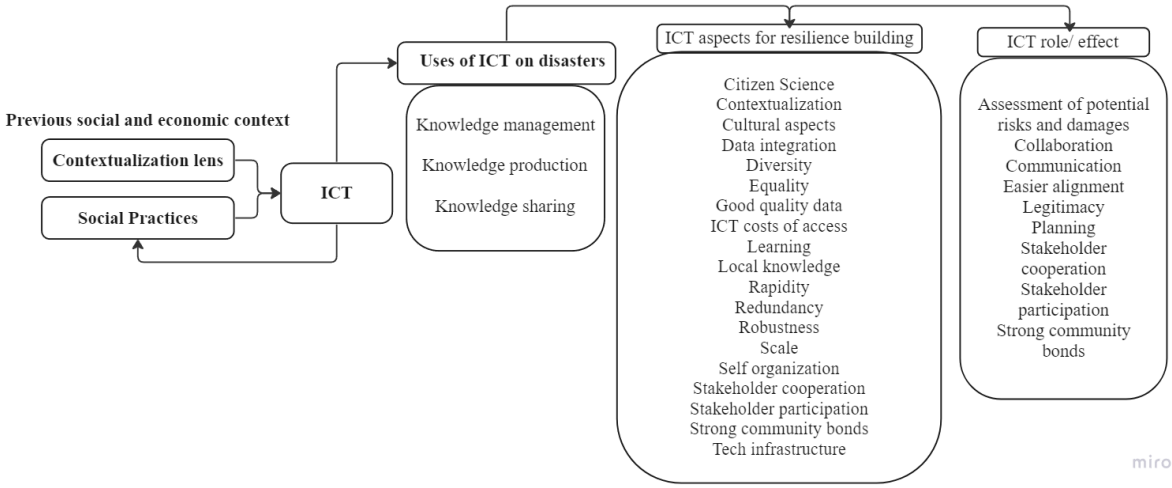

Figure 2. ICT and Resilience Framework for post-disaster scenarios.

Building up on the aspects and literature review, future agenda should focus on expanding the knowledge on the resilience aspects by: (i) understand on which cases those aspects are crucial; (ii) which are the most critical aspects for an effective resilience capacity building; (iii) how those aspects are related on a systemic perspective of resilience and risk; (iv) how those aspects are connected with the main concepts of resilience (resist, absorb, accommodate, recovery, BBB); (v) propose measurables indicators; (vi) develop a measurable framework for assessment of resilience in all the phases of a disaster, especially on the long-term post-D phase.

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