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Build Back Safely: Evaluating the Occupational Health and Safety in Post-Disaster Reconstruction

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Abstract: Current trends in disaster response and management include various stakeholders, including non-government organisations (NGOs), volunteer groups and other humanitarian organisations, working alongside governmental agencies. Together, they are directly involved in reconstruction efforts, with support often extending from the early response to long-term reconstruction. The common goal of reconstruction efforts spanning the last few decades is the ambition to "Build Back Better". More recently, there have been efforts to expand the scope of the reconstruction efforts to "Build Back Safer" and to raise awareness about the quality and safety of the final products, such as housing and infrastructure. Disaster management studies rarely address the construction process after disasters, or the working conditions of the builders, and often pay little attention to the health and safety of the extended workforce. This study identifies critical factors affecting workers, volunteers, local communities and other staff working on disaster reconstruction projects through a systematic literature review of academic publications. A total of 35 publications were thematically analysed, reduced from an initial selection of 394 publications selected between 2004 to 2022. The findings from this study highlight the vulnerabilities experienced by workers and the broader community involved in post-disaster reconstruction and acknowledge challenges integrating health and safety concerns into the practice and governance of global humanitarian systems.

Keywords: health and safety; post-disaster reconstruction; humanitarian agencies

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1. Introduction

Disasters have a tremendous economic impact, with estimates suggesting a global cost of USD 3.9 trillion over the last 2 decades, requiring more than USD 59 billion to reconstruct buildings and infrastructure damaged and destroyed by disasters [1]. Severe disasters have received significant aid contributions, including the 2004 Indian Ocean Tsunami, which attracted donations of USD 6.25 billion [2]. Such extensive humanitarian aid, coupled with pressures for rapid outcomes, creates significant challenges for reconstruction agencies. Issues such as the lack of coordination [3], poor government leadership, political interference [4], hurried responses, NGOs' lack of expertise in construction [3] and lack of accountability often hinder the reconstruction projects' management.

Efforts towards sustained recovery prompted the movement to "Build Back Better", a term coined after the 2004 Indian Ocean Tsunami [5]. This became the core for adequate recovery and reconstruction and was subsequently enshrined in the Sendai Framework for Disaster Risk Reduction in 2015 [6,7]. However, the humanitarian sector and researchers have questioned the "Build Back Better" ethos, as it does not explicitly address the structural safety of post-disaster reconstruction projects. Thus, academics and practitioners have proposed instead the idea of "Build Back Safer" [8]. The discussion around shifting from Build Back Better to Build Back Safer has prompted a series of proposals and guidelines for safer buildings to avoid risks for their occupants [8,9].

The construction industry is acknowledged as one of the most dangerous industries, accounting for a high percentage of work-related injuries and fatalities [10]. There is extensive literature exploring and analysing the issues impacting construction workers in the construction industry, although the discussion is centred on conventional construction activities [11]. The post-disaster contexts create unique environments, in which damaged and collapsed structures, flooded or unstable and contaminated soil, and the chaotic environment and rapidly changing local conditions impact the construction activities, magnifying the health and safety risks in conventional construction [11–14].

The objective of this paper is to address the gaps in the literature focusing on issues surrounding safety in reconstruction procedures and products under the "Build Back Safer" ethos. By doing so, this study underscores the importance of ensuring that issues around worker safety are addressed during the reconstruction process via a "Build Back Safely" approach. Therefore, this paper focusses on answering the following research questions: (1) What are the gaps in health and safety in the post-disaster reconstruction process? (2) What are the main factors that impact occupational health and safety in post-disaster recovery? (3) And what are the implications of health and safety issues in post-disaster recovery? This research is grounded on a systematic literature review of academic papers to identify critical issues impacting health and safety in post-disaster reconstruction. This study explores, analyses and synthesises the available research from academic sources, reports and documentation from humanitarian agencies, governments and NGOs.

2. Post-Disaster Reconstruction Process

Post-disaster reconstruction efforts begin immediately following the disaster [15], often operating in chaotic and overwhelming environments, before more structured response and recovery systems are in place. The long-term recovery and reconstruction process often extends from many months to several years [16], and requires strategic planning to identify and help the most vulnerable and severely affected people, as well as identify the rapidly emerging needs and priorities [17]. Furthermore, Priority 4 of the Sendai Framework for Disaster Risk Reduction refers to "Build Back Better" [4] as the requirement for a proper post-disaster recovery that minimises future risks, prepares for future disasters and promotes building resilience in the social, physical and natural environments.

In the aftermath of a disaster, the stakeholders involved are required to promptly determine the available resources, partners and assets of the affected communities, in alignment with their agendas and expertise [17]. Lindell [18] claims that disaster recovery encompasses multiple activities; some could be "sequentially implemented and others simultaneously". Practitioners and stakeholders also proposed stages to enable strategic planning of their operational directions and needed interactions during reconstruction. Figure 1 shows the activities and phases for post-disaster reconstruction, combining the NGO Habitat for Humanity International [19] model and complementing studies on post-disaster reconstruction, such as [15–18,20,21].

The phases and activities presented in Figure 1 primarily focus on reconstructing the built environment from the early works to long-term activities. Understanding the different approaches and the need to engage affected communities actively, activities promoting people's participation and making decisions and actions for their own "Self-recovery" [22], are included. Importantly, providing opportunities for people to make decisions about the reconstruction of their houses implies activities carried out beyond the completion of the construction of "core houses" and includes the assisted or non-assisted extension and modifications of these houses. The pre-disaster planning stage is also considered as preparation for a possible future disastrous event, which can be understood as the phase following the long-term recovery and reconstruction completion.

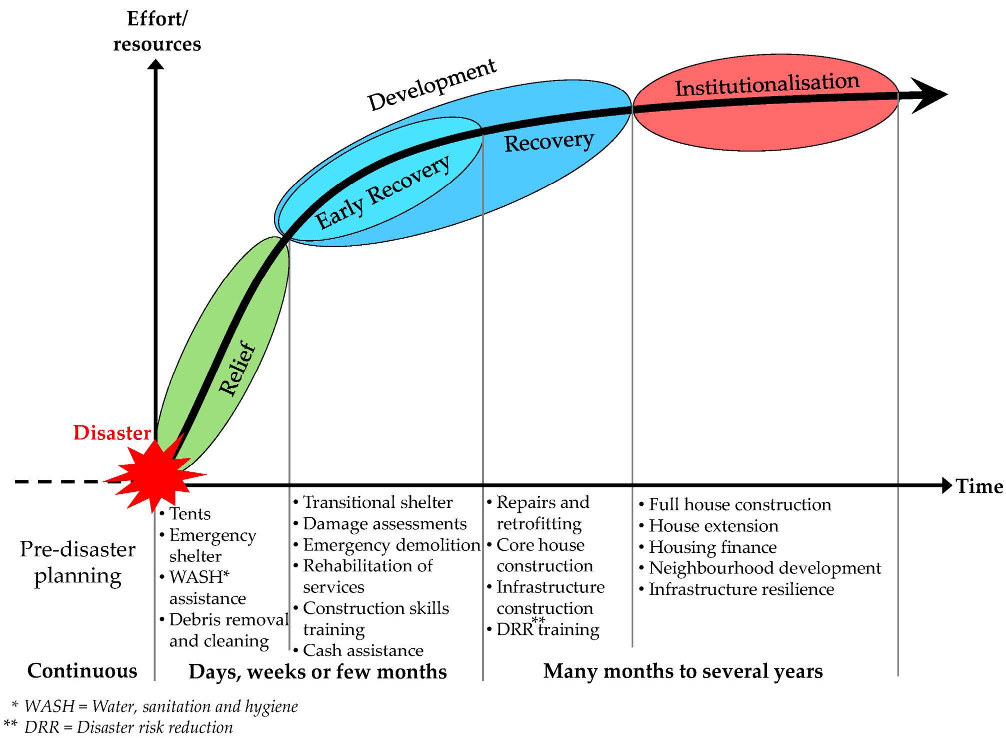

Figure 1. Process of post-disaster reconstruction. Authors based on [14,16–19].

3. Methodology

This study is based on a systematic literature review (SLR) of selected academic articles and the additional references and supporting literature from non-academic documents, such as from the government and reports from NGOs and other humanitarian organisations involved in post-disaster reconstruction. The process of a systematic literature review followed for this study considered the main guidelines for creating a robust approach in searching, evaluating and synthesising evidence [23,24] widely explored in management studies [25,26] and medicine and nursing research [24,27]. Literature review is essential in academic research, as knowledge advancement must be built on prior existing, rigorously conducted work, identifying gaps to explore the development of new theories and findings [28]. Furthermore, Xiao and Watson [28] claim that conducting a systematic literature review enhances these reviews' quality, replicability, reliability and validity. The following sub-sections present the literature search process, data extraction and analysis, and reporting followed for this study.

3.1. Data Sources and Search Strategies

Following the definition of the research questions, subsequent stages search for relevant studies addressing the key questions. A pilot search was conducted based on specific keywords. An Internet search was performed using multiple search engines: EBSCO Host, Web of Science (one of the most trustable scientific search engines; peer-reviewed articles and book chapters were part of the outcomes that were included in the initial screening) and Google Scholar (which included different sources and grey literature that provided references to other peer-reviewed documents). The reason for considering Google Scholar relies on the need to explore grey literature, such as articles, conference papers, reports and others, often published by academics and humanitarian agencies, which we otherwise might not be able to find and retrieve. Additionally, this study considered only peer-reviewed papers using this search engine.

The first step to start the selection of articles was to identify an initial list of keywords specific to the research objective and that allowed answering the research questions. The provisional list was refined as the literature review process started. The following keywords are relevant to the area of research related to post-disaster reconstruction and the health and safety of workers/staff/volunteers/builders/and others directly involved in the process, such as the organisations that manage the construction projects in this context:

Post-disaster recovery: post-disaster reconstruction; post-disaster assistance; disaster recovery; typhoon/cyclone/hurricane recovery; tsunami recovery; earthquake recovery.
Health and safety in construction: occupational safety; workers health and safety; staff safety; volunteers' safety; builders' safety.
Stakeholder management: humanitarian organisations; not-for-profit organisations, NGOs; volunteer groups; contractors.
Disaster recovery process: disaster waste management; relief; early recovery; recovery; long-term recovery.
Large scale disasters: Hurricane Katrina; Indian Ocean Tsunami; Great East Japan Earthquake/GEJE; Typhoon Washi; Typhoon Haiyan; Nepal Earthquake.

The second step included the search of articles, performed using Boolean operators as queries; this search system was observed to retrieve the largest portion of relevant records [29]. The search strings used for the selection of relevant documents was built by Boolean operators *AND-/*OR* [30] to search and access the relevant literature. The search strings used in this paper were: (1) "health and safety" AND "post-disaster reconstruction" OR "disaster recovery" OR "disaster relief" OR "long-term disaster recovery"; (2) "health and safety" AND "humanitarian worker" OR "humanitarian volunteer"; (3) "Safety" AND "humanitarian construction" OR "humanitarian architecture" OR "humanitarian engineering"; (4) "safety" OR "health" AND "post-disaster reconstruction" OR "reconstruction"; (5) "waste management" AND "disaster recovery"; (6) "NGOs" and "health and safety", "post-disaster recovery" AND "volunteers" OR "workers" OR "staff" OR "personnel"; (7) "Typhoon" OR "cyclone" OR "hurricane" OR "earthquake" AND "health and safety" AND "volunteers" OR "workers" OR "staff" OR "personnel"; (8) "crisis recovery" AND "health and safety" AND "volunteers" OR "workers" OR "staff" OR "personnel"; (9) "Hurricane Katrina" OR "Indian Ocean Tsunami" OR "Great East Japan Earthquake" OR "GEJE" OR "Typhoon Haiyan" OR "Nepal Earthquake" AND "health and safety" AND "volunteers" OR "workers" OR "staff" OR "personnel".

The timeframe considered was 2004 to 2022. The rationale for defining this timeframe is based on analysing the issues and challenges in the process of recovery in the aftermath of the Indian Ocean Tsunami that hit multiple countries in 2004. This disaster is widely acknowledged as a turning point for the global aid community, which triggered an unprecedented humanitarian crisis response [31].

3.2. Study Selection

The Preferred Reporting Items for Systematic Reviews—PRISMA statement [32,33] was used as a systematic review guideline for this study's phases of screening relevant references. The PRISMA flow diagram, shown in Figure 2, was used in this study to guide the literature selection process, which included four screening phases.

The first screening phase, or "Identification", included 342 papers retrieved from search engines and considered the keywords and titles that included the search strings described in the previous section. Duplicate papers and papers written in languages other than English were excluded. The second selection phase, "Screening", included 170 papers, in which the titles and abstracts were contrasted with the research objective and questions. Additionally, papers written before 2005 were excluded in this stage, as we considered the recent changes and advances in humanitarian work and post-disaster reconstruction. The third selection phase, "Eligibility", included 81 papers and focused on reviewing papers' titles, abstracts, findings and conclusions sections. The main concern for excluding papers in this stage was the relevance to answering the research questions and duplicated articles. The final phase referred to the "Included" articles for the analysis in this study and to answer the research questions.

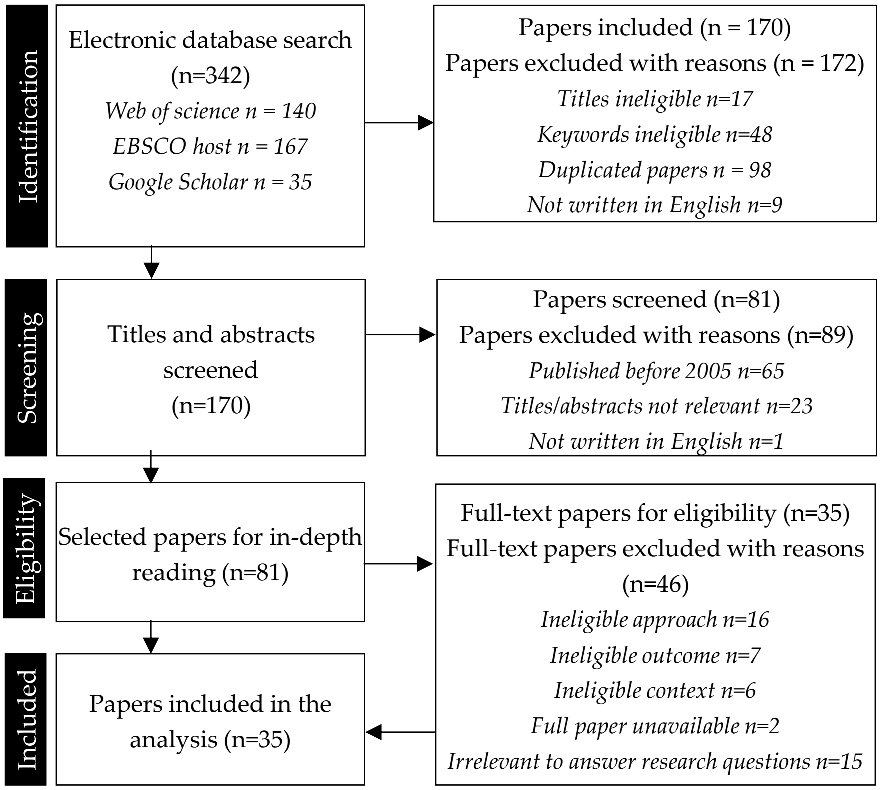

Figure 2. PRISMA diagram.

3.3. Characteristics of Included Studies

The publication year of the selected papers presents a relatively regular distribution throughout the established timeframe, with a 2015–2017 cluster of 12 papers (Figure 3). Twenty-four studies selected focus on specific case studies or disastrous events, and eleven focus on discussion of relevant issues and a literature review of different types of disasters. Figure 3 also presents the number of articles and the correlation with the major disasters identified within the timeframe and presented in the keyword list in the previous section.

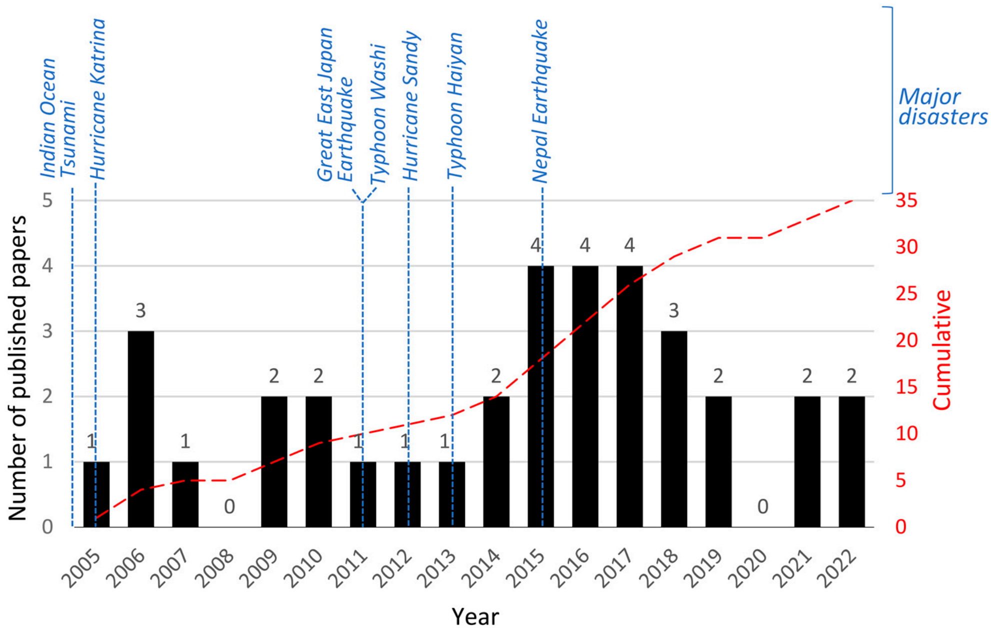

Figure 3. Number of publications by year.

Table 1 presents the list of publications selected for exhaustive review. The thirty-five papers selected include eleven journal papers, ten conference papers and one book chapter. The selected papers also focus on multiple geographical contexts, including countries from the Global North and South. The post-disaster response and recovery issues analysed covered multiple disaster types, such as floods, earthquakes, tropical storms or typhoons and hurricanes, and tsunamis. One article focused on the 2001 World Trade Center collapse. The papers selected also analyse the issues emerging in disaster recovery after events from different scales, for instance, disasters that prompted a global-scale response, such as the 2004 Indian Ocean Tsunami, the 2015 Nepal Earthquake or the 2011 Great East Japan Earthquake. In addition, small- or national-scale disasters, such as the 2020 Kumamoto Floods or the 2016 floods in Denmark, are also covered.

Table 1. Included papers for literature review.

No.	Authors and Year	Type of Publication	Year Published	Context	Disaster Event
1	Khalid, Nifa, Ismail & Lin [34]	Conference paper	2016	Malaysia	2014 Floods
2	Nielsen [35]	Journal paper	2019	Denmark	2016 Floods
3	Abdulquadri, Witt, Malalgoda, Lill & Amaratunga [36]	Conference paper	2018	Global	Multiple
4	Opdyke, Javernick-Will & Koschmann [37]	Journal paper	2018	Philippines	2013 Typhoon Haiyan
5	Chmutina & Rose [38]	Journal paper	2018	Nepal	2015 Nepal Earthquake
6	Sun, Chang-Richards, Kleinsman & Innes [39]	Journal paper	2021	New Zealand	2010–2011 Canterbury earthquakes
7	Uddin, Ganapati, Pradhananga, Prajapati & Albert [11]	Journal paper	2021	Nepal	2015 Nepal Earthquake
8	Bilau, Witt & Lill [40]	Conference paper	2015	Global	Multiple
9	Hayles [41]	Journal paper	2010	Global	Multiple
10	Grosskopf [42]	Journal paper	2010	USA	2005 Hurricane Katrina
11	Fernandez, Barbera & Van Dorp [43]	Journal paper	2006	Global	Multiple
12	Bilau, Witt & Lill [12]	Journal paper	2017	Global	Multiple
13	Uddin & Pradhananga [14]	Conference paper	2019	Global	Multiple
14	Esmaeili, Grosskopf & Javernick-Will [44]	Conference paper	2014	USA	2001 World Trade Center collapse
15	Bird & Grossman [45]	Journal paper	2011	Japan	2011 Great East Japan Earthquake
16	Izumi, Das, Abe & Shaw [46]	Journal paper	2022	Japan	2020 Kumamoto Floods
17	Carrasco, Ochiai & Okazaki [47]	Journal paper	2016	Philippines	2011 Typhoon Washi
18	Sukma [48]	Journal paper	2006	Indonesia	2004 Indian Ocean Tsunami
19	Tan [49]	Journal paper	2006	Indonesia	2004 Indian Ocean Tsunami
20	Scanlon, Helsloot & Groenendaal [50]	Journal paper	2014	Global	Multiple
21	Abdulquadri & Witt [51]	Journal paper	2016	Global	Multiple
22	Delp, Podolsky & Aguilar [52]	Journal paper	2009	USA	2005 Hurricane Katrina
23	Brown, Mefford, Chen, Callen & Brown [53]	Journal paper	2009	USA	Multiple
24	Thompson, Vaughan, Pearce & Moran [54]	Journal paper	2017	Global	Multiple
25	Karunasena & Amaratunga [55]	Journal paper	2015	Sri Lanka	2004 Indian Ocean Tsunami
26	Kenny [56]	Journal paper	2005	Indonesia	2004 Indian Ocean Tsunami
27	Fardhosseini, Esmaeili & Wood [57]	Conference paper	2015	USA	Multiple
28	Manuel [58]	Journal paper	2013	USA	2012 Hurricane Sandy
29	Sakuma et al. [59]	Journal paper	2015	Japan	2011 Great East Japan Earthquake
30	Brown [13]	Conference paper	2016	Costa Rica and Uganda	Multiple

Table 1. *Cont.*

No.	Authors and Year	Type of Publication	Year Published	Context	Disaster Event
31	Pamidimukkala, Kermanshachi & Jahan Nipa [60]	Conference paper	2022	Global	Multiple
32	O'Brien & Ahmed [61]	Conference paper	2012	Indonesia	2004 Indian Ocean Tsunami
33	Telford & Cosgrave [62]	Journal paper	2007	Indonesia	2004 Indian Ocean Tsunami
34	Carrasco & O'Brien [63]	Conference paper	2017	Philippines	2011 Typhoon Washi
35	O'Brien, Elliott & McNiven [64]	Book chapter	2017	Indonesia	2004 Indian Ocean Tsunami

3.4. Content Analysis and Synthesis

Following the selection of relevant publications in the previous section, the content analysis was conducted, focusing on the most relevant information to investigate the research questions using the coding framework [65] presented in Figure 4. Thematic analysis was used as a method to identify, organise and offer insight into a "pattern of meaning", referred to as "theme", that facilitates the understanding of collective meanings and experiences by researchers [26,66] The thematic analysis considered a coding and sub-coding approach to address more specific issues [67] identified as crucial to understand the occupational health and safety challenges in the post-disaster reconstruction process. The codes and sub-codes were defined after a first analysis of the papers, and the identification of the most relevant factors as main issues and indicators as sub-codes that provide more specificity in the issues related to the research questions.

Occupational health and safety in post disaster reconstruction			No papers	Process of post-disaster reconstruction: Relief	Early recovery	Recovery	Institutio-nalisation
	a. Context and site-related issues	a.1 Risk assessment and management	12	✓	✓		
		a.2 Initial relief and debris management	11	✓	✓		
		a.3 Hazardous materials and unsafe environments	20	✓	✓	✓	✓
		a.4 Construction and project management	4	✓	✓	✓	✓
		a.5 Integration of policies and standards	12	✓	✓	✓	✓
	b. Workforce management	b.1 Risks to mental and physical health	17	✓	✓	✓	
		b.2 Unskilled workers and untrained volunteers	20	✓	✓	✓	✓
		b.3 Workers' safety risk perception	14	✓	✓	✓	✓
		b.4 Imported and culturally diverse workers	14	✓	✓	✓	
		b.5 Local workers and spontaneous volunteers	14	✓	✓	✓	✓
	c. Organisational and management issues	c.1 Compressed timeframes	10	✓	✓	✓	
		c.2 Organisations' safety risk perception	11	✓	✓	✓	
		c.3 Organisations' expertise and capacities	16	✓	✓	✓	✓
		c.4 Education and training	26	✓	✓	✓	✓
		c.5 Communication and coordination	20	✓	✓	✓	
	d. Self-help and long-term recovery concerns	d.1 Self-recovery	8	✓	✓	✓	✓
		d.2 Long-term recovery	7			✓	✓
		d.3 Informality in construction	5		✓	✓	✓
		d.4 Governance and development issues	4			✓	✓

Figure 4. Coding framework.

In the first category, four themes were identified as areas related to broad contexts, such as the physical context (construction sites), human context (human resources and management), organisational (managerial dimension) and time (especially long-term, as it is rarely addressed). During the identification of codes and subcodes, it was evident that the issues impacting health and safety were closely related to the different stages of post-disaster reconstruction. Therefore, Figure 4 presents the coding framework and its relationships with the different stages of post-disaster reconstruction. For instance, the first two subcodes or indicators in the “context and site related issues” were predominantly present in the early recovery and recovery stages, while the following three subcodes were present in all the reconstruction stages.

Figure 4 also presents the relevance of the following codes and subcodes to the various stages of post-disaster reconstruction. Interestingly, the various issues identified are present in various reconstruction stages, including the “institutionalisation” or long-term recovery, where the implementing agencies might have more experience or have learned from the challenges in early stages.

Subsequently, the papers were analysed using NVivo 12, a software widely used for qualitative research analysis. Each theme and sub-theme were included as codes and nodes in NVivo, and the relevant sections in each selected paper were coded. Even though Figure 4 presents the correlation between the codes and subcodes with the different stages of post-disaster reconstruction clearly, the analysis in this paper focuses on the coding framework, which is analysed, summarised and presented in section four below. A further study should analyse the different issues identified and analyse their relevance in each of the post-reconstruction stages.

3.5. Limitations and Scope

This study focuses on the analysis of academic articles, considering the rigour of the analysis conducted with objectivity compatible with academic integrity. Furthermore, academic articles are subjected to a peer-review process, which enriches the quality of the studies. Non-academic documents, such as government reports, NGOs’ reports and other publications, are not included in the systematic literature review, as these might be biased toward the agency’s or organisation’s objectives and agendas. However, these documents are used as references to support statements emerging from the analysis and synthesis of the critical issues related to health and safety in post-disaster reconstruction.

4. Findings

The content analysis of the 35 selected papers is presented in Table 2. Table 2 shows the correlation between the papers’ contents and the identifies 4 factors and 19 indicators identified in the Coding Framework (see Figure 4) as key issues impacting the health and safety of workers in reconstruction projects. The analysis of the identified specific indicators are presented, grouped by the four factors: (a) Context and site-related issues; (b) Workforce management issues; (c) Organisational and management issues; and (d) Self-help and long-term recovery concerns.

4.1. Context and Site-Related Issues

Unique site conditions, particularly during the initial disaster response, relief and early reconstruction stages, creates environments where workers are exposed to multiple hazards that can be atypical to conventional construction work [60]. During debris removal, demolition and other early recovery activities, workers are exposed to contaminated environments and hazardous areas, where their physical health is at risk due to possible cuts, amputations, fractures and being trapped under rubble [11,40,42,51,60].

Identifying hazards, including contaminants, using salvage materials and communicating health and safety concerns and measures are crucial to minimise impacts on workers [12,43]. However, diverse studies reveal evidence that workers operating in a post-disaster context begin work despite any safety assessments. Bird and Grossman [45] observed that in the aftermath of the 2011 Great East Japan Earthquake, volunteers and contracted clean-up workers started clearing debris one month after the disaster, despite the lack of information about the potential radioactive contaminants. Workers wore cotton gloves and paper masks and had no specialised equipment. Additionally, access to damaged buildings was not restricted, despite continuing aftershocks [45].

Various studies [42,45,57] also point out less evident dangers, such as chemical and biological hazards. Fardhosseini, Esmaeili & Wood [57] observed that safety managers do not consider biological hazards as fatal risks during recovery operations. Biological hazards can impact workers' health, causing allergies, dermatitis, asthma and lung disease [42]. Biological hazards awareness has gained momentum during the COVID-19 pandemic. In the post-2020 Kumamoto Floods in Japan [46], workers and volunteers declined to participate in early recovery due to difficulties keeping social distance and personal hygiene. Consequently, untrained volunteers were recruited, prompting concerns about levels of safety and liability [46].

Following disasters, construction sites remain vulnerable to further hazards. For instance, in the reconstruction following the 2015 Nepal earthquake, workers and managers raised concerns regarding the ongoing instability due to the demolition and collapse of neighbouring structures due to ongoing aftershocks [11].

Integrating policies, such as building codes and regulations, and utilisation of adequate indigenous technology, materials and knowledge of local construction practice is crucial, especially considering the possible loopholes in the local regulations, which can create conditions of vulnerability in certain groups of workers. Bird and Grossman [45] reported that during the clean-up and recovery after the 2011 Great East Japan Earthquake, there was a lack of proper guidelines for managing hazardous and contaminated materials. Some American response workers under the U.S. government and some organisations in Japan followed guidelines from the U.S. Occupational Safety and Health Administration. Japanese workers involved in the recovery followed and were protected by Japan's health and safety laws. However, volunteers were not protected by these laws, received minimal safety training and were instructed to bring their own personal protective equipment (see Figure 5, left) [45].

Figure 5. Foreign volunteer gutting damaged walls in flooded houses in Ofunato, Japan, (**left**) and volunteers working on post-disaster housing reconstruction projects, Cagayan de Oro, Philippines, (**right**) without PPE and not following safety protocols. Authors.

Delp, Podolsky & Aguilar [52] highlight the limited local government agencies' capacities to fulfil their mission to protect workers' health due to inadequate government measures. These included allegations that the response measures were tinged with racism, resulting in disparate impacts in the context of the massive destruction caused by Hurricanes Katrina and Rita in the U.S.

Table 2. Summary of factors and indicators impacting health and safety in post-disaster reconstruction.

Factors and Indicators Impacting Health and Safety in Reconstruction	**Khalid, Nifa, Ismail & Lin [34]**	**Nielsen [35]**	**Abdulquadri, et al. [36]**	**Opdyke, et al. [37]**	**Chmutina & Rose [38]**	**Sun, et al. [39]**	**Uddin, et al. [11]**	**Bilau, Witt & Lill [40]**	**Hayles [41]**	**Grosskopf [42]**	**Fernandez, et al. [43]**	**Bilau, Witt & Lill [12]**	**Uddin & Pradhananga [14]**	**Esmaeili, et al. [44]**	**Bird & Grossman [45]**	**Izumi, Das, Abe & Shaw [46]**	**Carrasco, et al. [47]**	**Sukma [48]**	**Tan [49]**	**Scanlon, et al. [50]**	**Abdulquadri & Witt [51]**	**Delp, Podolsky & Aguilar [52]**	**Brown, et al. [53]**	**Thompson, et al. [54]**	**Karunasena & Amaratunga [55]**	**Kenny [56]**	**Fardhosseini, et al. [57]**	**Manuel [58]**	**Sakuma et al. [59]**	**Brown [13]**	**Pamidimukkala, et al. [60]**	**O'Brien & Ahmed [61]**	**Telford & Cosgrave [62]**	**Carrasco & O'Brien [63]**	**O'Brien, et al. [64]**
a. Context and site-related issues																																			
a.1 Risk assessment and management			✓				✓		✓	✓		✓		✓	✓	✓		✓									✓			✓	✓				
a.2 Initial relief and debris management							✓	✓		✓			✓		✓						✓	✓			✓		✓	✓			✓				
a.3 Hazardous materials and unsafe environments			✓				✓			✓		✓	✓	✓	✓	✓		✓			✓	✓			✓	✓	✓	✓		✓	✓	✓	✓		✓
a.4 Construction and project management							✓														✓	✓								✓					
a.5 Integration of policies and standards		✓	✓			✓						✓			✓	✓	✓	✓	✓			✓			✓								✓		
b. Workforce management																																			
b.1 Risks to mental and physical health							✓	✓		✓		✓	✓			✓					✓	✓		✓	✓		✓	✓	✓	✓	✓	✓			✓
b.2 Unskilled workers and untrained volunteers	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓		✓	✓		✓		✓		✓					✓	✓			✓		✓		
b.3 Workers' safety risk perception		✓	✓		✓		✓			✓		✓		✓		✓						✓	✓		✓		✓	✓		✓					
b.4 Imported and culturally diverse workers	✓		✓		✓	✓	✓			✓			✓	✓				✓	✓		✓	✓				✓					✓				
b.5 Local workers and spontaneous volunteers		✓	✓				✓			✓	✓	✓	✓			✓		✓		✓		✓				✓			✓		✓				
c. Organisational and management issues																																			
c.1 Compressed timeframes	✓				✓	✓	✓	✓	✓				✓								✓											✓	✓		
c.2 Organisations' safety risk perception			✓		✓		✓			✓	✓	✓		✓			✓					✓												✓	✓
c.3 Organisations' expertise and capacities						✓				✓		✓			✓					✓	✓	✓		✓	✓	✓	✓		✓	✓			✓	✓	✓
c.4 Education and training	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓	✓	✓		✓	✓	✓			✓	✓	✓			✓	✓	✓	✓	✓		
c.5 Communication and coordination	✓	✓				✓		✓	✓		✓	✓			✓	✓	✓		✓	✓	✓			✓	✓	✓			✓		✓		✓	✓	
d. Self-help and long-term recovery concerns																																			
d.1 Self-recovery				✓			✓										✓				✓					✓						✓		✓	✓
d.2 Long-term recovery				✓					✓								✓													✓		✓		✓	✓
d.3 Informality in construction					✓												✓					✓										✓		✓	
d.4 Governance and development issues									✓								✓															✓		✓	

4.2. Workforce Management

Workforce management is crucial for the safe, sustainable and successful completion of any construction project and impacts on workers' health and safety risks that may lead to construction accidents [11]. Grosskopf [42] identifies a series of health risks associated to post-disaster reconstruction, specifically in a post-hurricane context: electrocution from downed power lines or equipment failure; falls from heights; impacts from falling debris; exhaustion from working extended shifts in protective gear and clothing; heat stress from overexertion and dehydration; illness from chemical and biological contaminants; and trauma from heavy and handheld equipment.

In addition, the complexities inherent in this working environment produce distress among workers, particularly during the initial relief and cleaning activities, which might lead to long-term psychological impacts [11,46]. Construction workers are one of the first people who will arrive in an area that has been hit by a disaster and will be exposed to numerous psychological hazards. Various kind of stress, such as physical and emotional, can cause fatigue, emotional withdrawal and depersonalisation. By obtaining social science knowledge, safety managers might decrease the risk of work stress among workers [57]. Extended working hours due to lack of personnel, tight timeframes, workers' livelihood and economic pressures are common in post-disaster reconstruction, which might seriously impact the workers' wellbeing and risk awareness and judgement to avoid accidents [14]. Furthermore, the interaction with disaster-affected communities and the workers' precarious living environments magnifies their stresses. The impacts to workers' mental health increase the probability of accidents at workplaces [11,14].

Post-traumatic stress disorder (PTSD) is a common effect of highly stressful environments. Disasters can increase the chance of psychological disorders, such as depression, panic disorder and anxiety, among workers. First respondents, such as firefighters and health care workers, are observed as vulnerable staff with a prevalence of probable PTSD and depression due to experiences related to lack of rest, dead or missing family members and near-death experiences [59,60]. Furthermore, construction workers in conventional sites have experienced suicidal behaviours triggered by stress, fatigue, low morale, financial crisis and PTSD and are two and a half times more likely to commit suicide compared with other professionals [68]. These profound mental impacts are expected to be magnified by the nature of the working conditions in post-disaster reconstruction sites [11].

The complex process of disaster recovery from early relief to long-term reconstruction implies the engagement of multiple stakeholders, such as government agencies, local and international non-government organisations (NGOs), community-based organisations (CBOs), volunteer groups, religious organisations and individuals. Formal workers, such as organisations' staff, including workers and volunteers, often receive training and debriefing sessions, including health and safety and proper use of protective equipment. *The Sphere Project Handbook* is one of the oldest and most well-known guidelines, compiling minimum standards for humanitarian response and aiming to support policy development and advocacy to uphold principled quality and accountability. *The Sphere Handbook*'s standards provide guidance to humanitarian organisations working onsite in emergency assistance and recovery operations [69], and it stipulates in Commitment 8, Organisational responsibilities, that "*agencies exercise a duty of care to their workers. Managers make humanitarian workers aware of risks and protect them from exposure to unnecessary threats to their physical and emotional health*". However, the limited workforce availability and organisational pressures often lead to the spontaneous engagement of volunteers, local communities, imported and culturally diverse workers, and other people with limited skills [46,48,50,52,58,60]. Pamidimukkala, Kermanshachi & Jahan Nipa [60] refer to three categories of construction workers: unskilled workers, semi-skilled workers and skilled workers. The different skill levels among workers might determine their awareness of the risks, knowledge and decision-making capacities. For instance, the use of unfamiliar equipment, including basic training on the use of personal protective equipment (PPE) [11], and the lack of communication can lead to health issues for the workers and their colleagues [60] (see Figure 5, right).

The studies reviewed point out that humanitarian agencies, contractors and other organisations involved might use unskilled workforce to expedite the reconstruction process. However, this practice implies more safety risks and confusion on the site, compromises efficiency and contributes to workers' exposure to fatal hazards [11,35,43,46]. Nevertheless, engaging untrained and unorganised workers and volunteers remains a common reconstruction practice (Figure 5, right).

In the context of a scarce workforce, organisations carrying out post-disaster reconstruction projects choose to import workers or involve international volunteer groups. For example, NGOs involved in the post-Indian Ocean Tsunami in Indonesia recruited technical engineers and construction professionals from other countries and incorporated workers and volunteers from other regions, who can be unfamiliar with procedures and local conditions [70]. In the reconstruction efforts after Hurricane Katrina, 70% of workers were U.S. citizens from other states and foreigners from Mexico, Honduras and El Salvador [71]. In the aftermath of the Great East Japan Earthquake, cleaning activities heavily relied on national and international volunteers [63]. In addition, local construction businesses temporarily transferred employees from other regions of Japan to support their understaffed operations in the Tohoku region [39].

It is also important to acknowledge the increasing participation of migrants and culturally diverse and other minority groups in post-disaster reconstruction. For instance, immigrants and U.S.-born Hispanics compose an increasing percentage of the recovery-after-disaster labour force. These workers are typically young and with limited English-speaking abilities and are engaged in low-skill and high-risk occupations [72–74]. These factors have made Hispanic workers more vulnerable when employed in post-disaster recovery operations, as translating training materials is not enough, but requires addressing several cultural and language barriers [44]. In addition, migrant and imported workers experience further stress due to their immigration status and lack of rights and health insurance. They usually fear deportation, incarceration and lack of medical attention in the case of accidents [52].

4.3. Organisational and Management

Issues regarding the capacities, approaches and operation of post-disaster recovery and reconstruction projects create vulnerable conditions for workers and volunteers' health and safety. A frequently mentioned organisational issue is the pressure for rapid reconstruction, which compromise the health and safety of post-disaster reconstruction projects [11,14,40,46,61,62]. Reconstruction programmes are often funded by domestic and external sources, in which the financing resources are concentrated on relief and early recovery and are reduced in later stages, causing tremendous pressure for middle- and long-term reconstruction [75]. Uddin & Pradhananga [14] refer to the effects of rush in the implementation of reconstruction projects associated with inefficient site assessment and planning, causing an increase in the probabilities of suffering from 'exposure to hazardous and contaminating debris', 'building back faster syndrome', 'imported workers' and 'post-traumatic stress disorder', which are some of the significant health and safety factors not seen in regular construction. Organisations managing reconstruction often experience competition for financing their projects, requiring stringent timeframes to spend allocated funds before receiving further resources [76,77]. Uncoordinated reconstruction can lead to overlapped and rushed operations, compromising the construction's efficiency, quality and safety [40,70,78].

Research by Abdulquadri, Witt, Malalgoda, Lill & Amaratunga [36] revealed that organisations implementing reconstruction projects struggle to comply with building codes and regulations and health and safety guidelines. Additionally, balancing the imposition of varying health and safety standards due to the diversity of donors or partner agencies with equally diverse health and safety expectations and non-alignment of local construction industry expectations negatively influence the organisations' awareness of health and safety exposure to workers and beneficiaries [36]. O'Brien, Elliott, & McNiven [64] stressed the risks of using asbestos panels to construct permanent housing in Aceh, Indonesia. Their study highlighted that, despite asbestos being banned in many countries due to the high risks associated with these materials, the NGO responsible for building the houses took advantage of the loose local regulations in the use of lightweight asbestos panels (Figure 6, left). Furthermore, the study claims the long-term impact of using hazardous materials can extend to users and future builders in these sites.

Figure 6. Housing originally constructed with asbestos panels is gradually being replaced by bricks in Neheun, Aceh, Indonesia, (**left**) and incremental post-disaster housing with planned extensions in Villa Verde, Constitucion, Chile, (**right**). Authors.

Organisations' capacities to deploy experienced and trained personnel for monitoring and control during projects' implementation is crucial to minimise occupational risks [12], particularly, the building capacities of disaster response professionals and effectively sharing knowledge of strategies for both self-care strategies and supporting colleagues to reduce the risks and mistakes that could harm workers or the communities they are serving [54]. Other organisations venture to implement housing reconstruction projects without expertise to justify the expense of available funds, such as in the case of the reconstruction following the Indian Ocean Tsunami, mainly in Indonesia [51], and the Typhoon Washi in the Philippines [63]. The deficient construction put the workers at risk and negatively influenced the quality and durability of the houses.

Capacities to carry out training on construction skills and health and safety presents multiple challenges for organisations implementing reconstruction projects. Organisations' limitations understanding the issues and identifying effective approaches for engaging different kind of workers, such as volunteers, local and spontaneous workers, imported workers and culturally and linguistically diverse workers, might contribute to the creation of risks on the already complex post-disaster reconstruction sites. For instance, Chmutina and Rose [38] question the effectiveness of "on the job" training, how trainees understand and apply the knowledge, and how workers' relationships with the organisations might influence the outcomes.

4.4. Self-Help and Long-Term Recovery Concerns

The health and safety issues in post-disaster reconstruction mostly focus on managing and implementing projects in the short and middle term from the organisation's perspective. Top-down approaches differ from community-driven and owner-driven approaches, which have been identified as more effective at supporting the active participation of disaster-affected people, especially in housing construction [51,56]. Humanitarian organisations are recently highlighting the fact that disaster-impacted people never remain passive and reconstruct their houses themselves or hire local workers, with or without support from humanitarian organisations, in a process referred to as "self-recovery" [22,79].

Post-completion owner-driven construction has long-term impacts that can last for many years and is subject to the changing people's needs and preferences [47,61]. Therefore, there is a missing stage to be incorporated into the analysis of the risks for health and safety in reconstruction projects, which should include a post-completion stage. Construction technologies applied, materials used and quality achieved during the post-disaster housing construction directly impact the residents and local construction workers, who will be involved in the replacement of construction elements, construction of housing extensions and modifications made to the original houses [47,64], as seen in Figure 6 (left and right).

Brown [13] claims that "safety does not stop with the completion of construction" and responsibilities of safety operators and maintainers should be considered. Handover of the information about future safety needs to be facilitated to the community or the operator should be considered. In addition, Brown [13] also claims that clear training should be given to those taking over, and residual risks should be highlighted. Even though organisations responsible for housing reconstruction projects often leave upon the completion of their projects, some decide to keep working with communities, or government agencies might take the responsibility to ensure the wellbeing of disaster-affected people and carry on needed maintenance works in coordination with residents [63].

Post-completion construction works are managed mainly by the people themselves, which might also be facilitated by government funding or supported by NGOs and volunteer groups [47,61]. Studies noted that local policies often restrict the self-help construction of housing extensions, arguing that allowing them would promote informal and illegal construction and re-create pre-disaster vulnerabilities [47]. Consequently, NGOs or other organisations are discouraged to support communities in promoting safe construction practices and technical assessment dismissing the potential hazards to the health and safety of the residents who perform the construction works themselves or skilled or unskilled local construction workers [47]. Social and post-disaster housing projects from Chile offer opportunities to channelise resident-led construction, providing guidelines to perform planned extensions within a structural framework [80]. Designers claim that by providing a safe structural framework, homeowners may build based on designers' guidelines [80] (Figure 6, right), although studies evidenced that many build beyond these "pre-packaged" alternatives [81,82]. Therefore, raising awareness about safety in construction is necessary, which perhaps could be incorporated as part of the project design.

5. Discussion

This study has identified multiple factors and indicators that affect the health and safety of workers involved in post-disaster reconstruction. Recognising the particularities of post-disaster reconstruction contexts compared to conventional construction is crucial to understanding the specific safety construction challenges. Construction is widely acknowledged as a high-risk industry, although in post-disaster reconstruction, the construction risks are magnified, and context-related hazards create new risks related to the workforce, site and management, and construction process in certain stages or phases of the complex reconstruction and recovery. Additionally, understanding the risks for physical health and acknowledging the psychological risks are important to properly address the health risks that might emerge onsite.

The findings pointed out that occupational health and safety (OHS) risks are associated to the construction activities required in different reconstruction phases. Even though in many cases the reconstruction phases overlap and might not be clearly distinguished, there are critical stages that require higher attention. For instance, early recovery activities, such as demolitions and debris cleaning, might require a more extensive assessment of the local conditions, explore the challenges for workers' health and safety, designing and implementing projects with prepared or trained personnel to undertake the required tasks.

The literature about health and safety in post-disaster reconstruction rarely integrate the type of workforce involved beyond skilled and unskilled workers. However, this study highlights the engagement of volunteers who could be international, exclusively arriving to support recovery, or spontaneous local communities engaged as volunteers or motivated by financial pressures. Experienced humanitarian organisations and inter-agency coordination committees, such as the Shelter Cluster (See: https://sheltercluster.s3.eu-central-1.amazonaws.com/public/docs/gsc-construction-good-practices-jan2018-dp.pdf (accessed on 10 December 2022)), often have health and safety plans and guidelines that emphasise the management of skilled workers, spontaneous volunteers and local people. However, their implementation and monitoring might be subject to the organisation's approaches and expertise or whether they are part of the inter-agency coordination body. Furthermore, this study also highlights that imported workers, culturally diverse groups and members of minority groups might require different approaches to raise risk awareness and implement safety plans.

Post-disaster reconstruction approaches, such as community-led or resident-led housing reconstruction, require training in construction safety for the builders, who could be the local people themselves. The alignment of the humanitarian organisations, contractors and others involved in reconstruction are required to comply with local construction standards, including workers' health and safety. However, this study also presented that certain organisations might find inconsistencies between local and international standards and loopholes in local policies, and implementing organisations might choose to follow the lower standards. Consequently, the project implementation would pose higher risks for construction workers and have long-term impacts beyond completion and future construction works after the organisations and contractors leave the sites.

6. Conclusions

This study identified key factors and indicators impacting occupational health and safety in post-disaster reconstruction related to working in chaotic and high-risk environments, addressing issues of various types of workforces and understanding the organisational issues and capacities that emerge at various post-disaster recovery stages.

The literature review evidenced gaps in the discussion of occupational risks in construction activities after disasters, such as volunteer engagement and people's self-help construction initiatives during the reconstruction process or in a post-completion stage. These issues are highly relevant in the context of the increasing frequency and intensity of climate-change-related hazards. The need to ensure safe construction practices that focus on the construction process, fostering "Build Back Safely", rather than the finalised product is vital, as the humanitarian sector is moving towards active people's engagement and participation approaches for their own "self-recovery".

The diverse occupational risks in construction involve developing a resilient safety culture, which requires reinterpreting approaches in conventional contexts, such as project design strategies proposed by [80–82], and exploring opportunities to adapt them to post-disaster reconstruction. These would be further incorporated into the protocols of humanitarian organisations, contractors and government agencies involved in reconstruction projects.

Additionally, further studies are required to analyse the integration of "Build Back Safely" in diverse context of crisis impacting the built environment, such as armed conflict and displacement, which require rethinking approaches to guarantee the safety of workers involved in reconstruction. Analysing the issues and best practices in conventional construction, post-disaster recovery and post-conflict reconstruction benefits the discussion towards producing a culture of safety for construction works in diverse emergency contexts.

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