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Article

Structural and Spatial Minimal Requirement Efficacy of Emergency Shelters for Different Emergencies

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Abstract: Natural and human-induced disasters have become more frequent in recent years, and this has increased the need for effective, high-quality, quick, easy-to-assemble, and affordable emergency housing solutions. The purpose of this study is to create a knowledge base for researchers and developers working in the structural and structural-related fields to favour the development of relevant and most appropriate assistance for emergency housing that could meet the anticipated future rising demands. The focus of the research is emergency shelters for the Global South, an area of research sparsely addressed within the structural-related field. The emergency sheltering process has so many variabilities in its duration and unfolding that many agencies suggest relying on the resilience of those in need. This can have dramatic human repercussions and eventually further burden natural resources. To reach its goal, the paper shifts the attention to information from field actors and global agencies and employs a multiple case studies approach, conducted through a grounded theory methodology. The process has allowed identification of a list of structural-related issues faced by users, acting as codes in the grounded theory methodology, the associated challenges for authorities in addressing them, acting as categories, and some ideal solutions, derived from the theoretical coding. The research concludes that the challenges of the sheltering process shall be read through sustainability housing indicators and that the constraints of the former may be stimuli to the application of innovative and more inclusive procedures within the latter. The study fosters a new theoretical approach in post-disaster housing, which encourages more interdisciplinary collaborations and empirical investigations that will potentially enhance post-disaster housing sustainability and facilitate the development of emergency shelter construction schemes.

Keywords: shelter emergency; sheltering process; emergency housing; post-disaster; spatial requirements; transitional shelters; grounded theory; Global South

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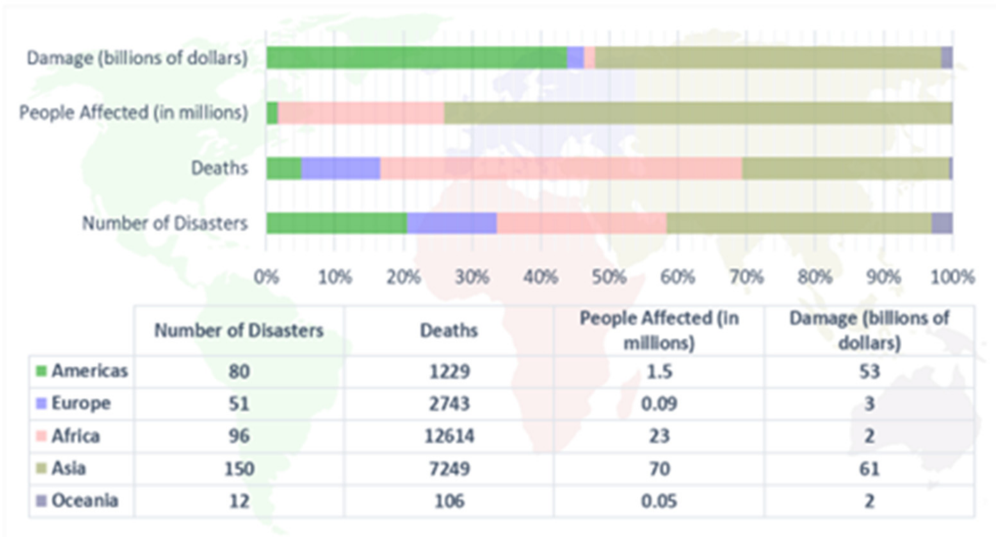
1. Introduction

Motivation and Objectives

Emergency housing or shelters become essential when living conditions have significantly deteriorated, they have fallen, or are on the verge of falling below ordinarily accepted minimum humanitarian standards. A country's environmental, social, and economic conditions influence what is judged as 'inadequate housing/shelter'. The term 'emergency' in general refers to either nature-induced disaster situations for which only the negative consequences are manageable or human-induced disasters/accidents where careful planning and prevention play a key role. Recent population growth, economic crisis, as well as ongoing environmental challenges, have blurred the line between the two scenarios [1]. At present, it is estimated that one in eight people around the world is living in inadequate shelters. In the next 10 years, it is estimated that more than three billion people will need adequate housing [2]. Figure 1 shows on a global scale the increasingly exposed population to disasters. Cascade effects are such that the composition of affected groups varies greatly from homeless individuals to scattered persons within an area up to the entire population within a geographically enclosed area of variable extension [3]. Figure 2 illustrates the predicted world population affected by inadequate housing/shelter estimation for 2025. The numbers consider internal displacement from conflict, violence, and natural disasters, but may or may not consider chronic and transitional homelessness, making direct comparisons of numbers complicated. Regardless of the method used for estimation, risk creation is outstripping risk reduction [4]. As laid out in the Geneva UN Charter [5], the UNECE region advocates for an integrated, strategic approach to housing developments that encompasses economic, environmental, and sociocultural factors (see Figure 3). On the other hand, Priority 4 of the UN Sendai Framework for Disaster Risk Reduction [6] emphasizes building resilience in parallel with reducing and preventing risks. However, pushed by society facing the lack of temporary sheltering facilities for hospitalization during the COVID-19 pandemic, the surge of homeless people [7,8], the resurgence of armed conflicts in developed countries, government or state politics focus on risk and tend to overshadow long-term recovery [9] and emergency preparedness [10]. Meanwhile, international agencies propose resilience strategies and cash support to cope with the emergency. In many countries, however, housing policies are still under development, while refugee conditions are precarious. Eventually, makeshift or poorly planned solutions risk moving toward a direction opposite to the sustainability housing goals.

Unfortunately, disasters happen, and the provision of emergency shelters will always be one main aspect of the recovery process. Whenever the action of national agencies is limited, non-governmental organizations (NGOs) oversee the emergency sheltering process. However, according to [11], NGOs find difficulties in formulating long-vision strategies and involving research due to the demand-driven nature of shelter and few resources to retain and develop expertise in the leading roles. Climate change adds to the difficulties. The International Federation of the Red Crescent and Red Cross (IFRC), which is the biggest humanitarian network working on disaster relief, is devoting large effort to preparing guidelines to support their volunteers and the local communities in the proper installation or construction of shelters [12]. The United Nations High Commissioner for Refugees (UNHCR), the largest customer of emergency shelters, has started following the same approach [13]. This article investigates the issues of the emergency sector, with a focus on the Global South, starting from reports from the field and international agencies.



	Number of Disasters	Deaths	People Affected (in millions)	Damage (billions of dollars)
Americas	80	1229	1.5	53
Europe	51	2743	0.09	3
Africa	96	12614	23	2
Asia	150	7249	70	61
Oceania	12	106	0.05	2

Figure 1. Occurrence, deaths, affected population, and damage of disasters. Adapted from [13] (p. 15).

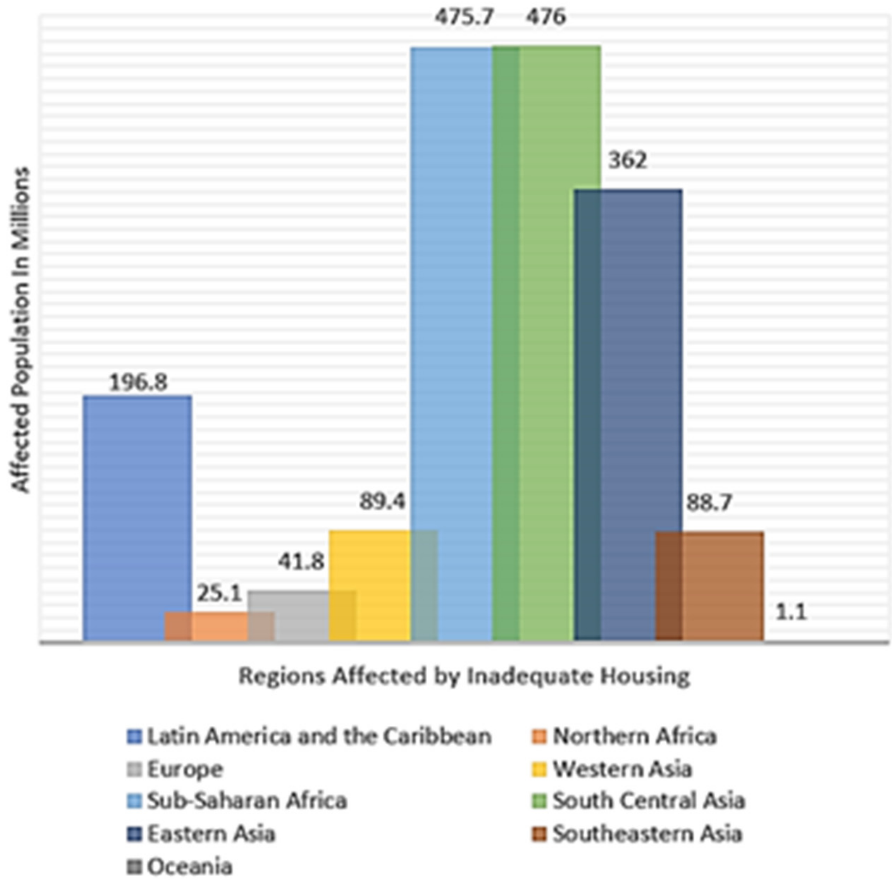


Figure 2. World population affected by inadequate housing, estimation for 2025. Adapted from [2].

Figure 3. The Geneva UN Charter on Sustainable Housing. Reprinted from [6].

Providing structural information is particularly important in the emergency housing process. In 2010, the World Bank recognized that the only sustainable solution in this sector is to rely on the resilience of those in need [14]. The biggest challenge is dealing with its ramifications and unpredictable consequences. A disaster is indeed a loss or impact of such scale that it renders a society incapable of coping with, absorbing, and recovering from such crises using its capabilities [3]. This research aims to understand what the space of action of structural-oriented research could be. Within the research community, the environmental [15], economic [16], and socio-cultural [17] fields stress the need to address the sustainability of the emergency housing process. Meanwhile, the architectural research community follows a case-specific approach, proposing idea competitions [18], involving students [19], running post-evaluation surveys [20], and fostering politicization [21]. The civil engineering community [22] on the other side is advocating for prefabricated constructions, discussing metrics, and in case-specific circumstances, offering support for structural testing of vernacular structures [23]. Within the sustainable framework, this paper examines whether structurally related research reads for the challenges of the emerging housing process and if the research on the emerging sustainability indicators can be used to assist it. This article broadens the perspectives and applies a theory building from multiple case studies (TBMCS) research approach [24], an inductive strategy aimed to answer "how" and "why" questions that bridge from rich qualitative evidence to mainstream deductive research [25]. The study applies a grounded theory methodology, whose principles and implementation are exposed in Section 3. It is worth noting that the approach typically produces no quantifiable data, but produces robust, generalizable, and testable theories due to its reference to multiple case studies. In this context, it has enabled the formulation of a series of propositions, which clarify research gaps and identify good pathways within a sustainability framework. In Section 4, by investigating the technical issues read from the case studies, the paper addresses which structural-related challenges characterize the sector, with a focus on transitional shelters for the Global South. Section 5 verifies if the needs of the sector are accounted for in the sustainability indicators, and vice versa if strategies to increase resilience can be envisioned. Section 6 summarize the research findings and unfold their implications: the shelter process shall be addressed within the sustainability housing goals. Properly addressing the sheltering process can foster research and solutions whose benefits also exceed the sheltering itself.

2. The Emergency Housing Process

This section briefly introduces the emergency sector and a few definitions to the reader who does not have related experience. Disregarding emergencies where the affected persons leave their houses for a few hours after the crisis due, for example, to interruption of utilities, as shown in Figure 4, adapted from Flores and Kloer [26], exemplifies the possible three stages within the recovery process: temporary, transitional, and permanent housing. These are based on the classic distinction by Quarantelli [27] based on the possible situation of the affected persons. In accordance, temporary shelter is a temporary stay arrangement such that the persons do not recover routines. On the contrary, transitional shelter [28], which Quarantelli defined as temporary housing, is a temporary stay arrangement such that the persons recover routines but suppose not to stay permanently. Finally, permanent housing is the institutionalized restoration of permanent residential conditions. The situations affect the expected durability of the shelter and are used within this paper in Section 3 for the organization of the case studies. Currently, almost 70% of the world's refugees live outside organized camps and more than 65% of the refugee situations become protracted [29]. The ability of the affected family (A in Figure 4a) to reach a permanent housing solution determines the appropriate emergency housing pathway. Furthermore, according to [30], more than 80% of refugee crises last for ten years or more; 40% last 20 years or more; internally displaced people (IDP) in countries under conflict-related or forced displacement take over 23 years to stabilize. Given that the duration of the transition to permanent housing is variable, the structurally oriented reader may find it difficult to define a transitional shelter of its durability, which is due primarily to the durability of its structure, shall last the entire transitional period until permanent solutions are possible. Indeed, blurred boundaries exist between the typologies of shelters [30] that literature lists within each family of shelters. To address the inconsistencies, most recent literature stresses the focus on the sheltering process. In [31], sheltering has been defined as "an enabled process to facilitate a living environment with crisis-affected communities and individuals, to meet their current and future needs, whilst also having due consideration for the needs of the host communities and environment" [31]. The definition is linked to sustainability goals. This paper will further demonstrate that the need for physical shelters is linked to the opportunity to develop sustainable housing.

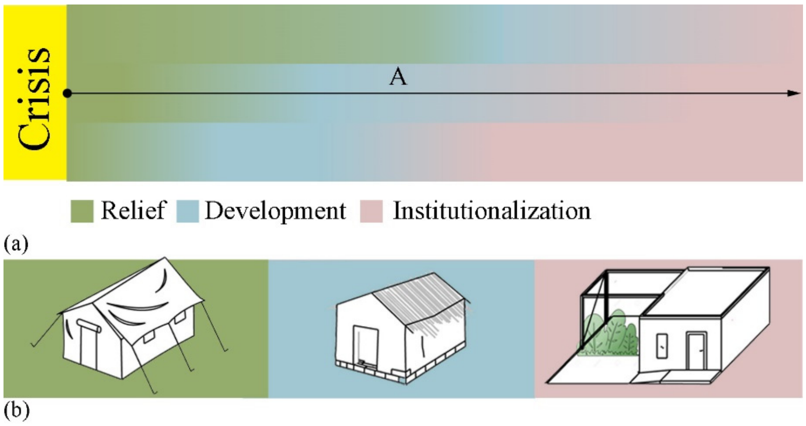


Figure 4. (**a**) Emergency shelter based on crisis-recovery timeframe. Adapted from [26] (**b**) Typical temporary, transitional, and permanent shelters.

3. Research Methodology and Materials

3.1. Methodology

By analysing multiple case studies, this research aims to gain qualitative insights into directions and research gaps within the structural research on emergency shelters. Hence, the study follows a grounded theory research methodology, a typical qualitative approach that allows inducing theories from the analysis of data (see Figure 5) [32]. This research methodology is flexible yet systematic. Briefly, it consists of cyclic phases of coding the data and categorizing it, in such a way as to move toward increased abstraction and generalization [33]. The theory emerges from the cycling process in the form of themes, called theoretical coding, which allows an understanding of the data. The data analysis part of this approach requires theoretical sampling, which is searching for additional relevant data until the problem is saturated [34]. Whether the codes and categories are in accordance with the data ensures the validity of the theory. As the process unfolds, codes and categorization are adjusted to match the old data with the new data, taking notes on the way. These notes and the theoretical coding eventually form propositions that comprise the theory. The application of the process in this research is summarized hereafter.

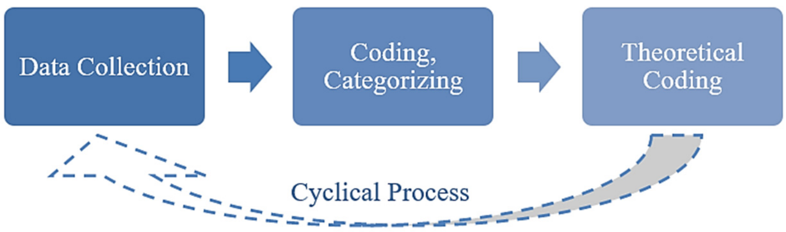


Figure 5. Scheme of the grounded theory research methodology used in this study.

The structural-related issues in emergency shelters function as input codes. They have been formulated from the analysis of shelters deployed in real emergency scenarios, which have been collected here ensuring consideration of different emergency types, shelter categories, and structural typologies. From a structural viewpoint, it was found that the vast majority of shelters are one-story structures, mostly with timber frame roofs, whereas the vertical load-bearing system presents a variety of solutions. The structural-related issues have been collected, analysed, coded within structure-related issues, and associated with the transcripts expressing the physical characteristics and procurements of the shelters. After evaluating 80 shelters, the list of structural-related issues was saturated, and it was possible to reduce the list of shelters to 24 representative case studies. The categorization process had two cycles. The list of issues, acting as codes, have been associated initially with structure-related indicators, and eventually with the challenges behind the most significant indicators. The first cycle of the process was performed through a Kesselring matrix, also used in [35] to study the characteristics of a temporary shelter. The issues of each shelter were associated with the shelter's typology, structural typology, materiality, the type of emergency, and procurement process. There was no significant correlation between emergency type and structural challenges. The shelter's typology was the most significant indicator. Transitional shelters present more frequent and more diverse issues compared to permanent ones, which tend to be assimilated by sustainable housing research. Meanwhile, temporary shelter solutions show signs of progress and the emergence of procedures. Eventually, more information, therefore, was collected about the structural requirements of transitional and temporary shelters, and the challenges were listed. This second cycle of the categorization process aimed to better understand the space of action of structurally related research in addressing the challenges and employed an interrelationship matrix to search for dependencies between them. The methodology is suggested to group-analyze the natural links between different aspects of a complex situation [36]. Finally, the theoretical coding was conducted by comparing the identified categories with the categories that emerged in the sustainability housing research. The Sustainable Housing Assessment Tool (SHAT) proposed in [37] has been chosen for the scope because it implements the Geneva UN Charter, it is derived by a thoughtful review, and, wherever possible, expresses the indicators with a unit of measure.

3.2. Research Limitations

Since Africa and Asia have the highest incidence of disasters with large populations of affected people (as illustrated in Figures 1 and 2) [2,13], to obtain an effective output, this study focuses on the emergency housing process in these regions. The emergency shelters considered are the ones deployed during actual housing emergencies (including a few pilot projects) in recent years, and thus do not focus much on conceptual designs which are under development or in the market. In terms of the structural perspective of this study, shelters that are structurally dependent and/or within an existing structure/building are excluded. This is the case for example of the fangcang cubicle employed by the Chinese government within existing infrastructures in response to COVID-19. Similarly, fallout and anti-terrorism shelters are disregarded as they are typically constructed within an existing building. A part of the analysis has included the homeless emergency sheltering process which includes the provision of temporary to semi-permanent shelters. Several national policies leverage the existing housing stock to offer temporary shared accommodation to be integrated into housing plans. In such considered cases, a housing stock may not be present, but the emergency sheltering process, whereas being subjected to complex constraints, shall still target to reach sustainable housing policies.

3.3. Data Collection

The selected list of case studies in this study was generated based on the Global Shelter Cluster technical reports [38,39], which gather activities from UNHCR, IFRC, partner agencies and organizations, as well as United Nations Children's Fund (UNICEF) [40,41], well-established NGOs like Médecins Sans Frontières (MSF), and newer ones like the Ikea foundation Better Shelter. According to the grounded theory approach, complementary and opposite data shall be searched to test the validity of the findings. Emergency responses implemented by the US Federal Emergency Management Agency (FEMA) [42], and national agencies in Europe [43] have been considered. In such cases where the description of the shelter's characteristics was somehow lacking, it was integrated by searching journal papers, magazines, and product pages addressing the disaster. Since official reports select shelters that have been employed in high numbers, a few pilot shelters from the architectural and engineering community as well as hazard-specific shelters coming from the industry were also analysed to evaluate the findings. The process of selecting such shelters from grey literature has followed the guidelines in [44]. For the categorization process, the shelters' requirements were analysed considering the recent UNHCR sustainability assessment criteria [45], the series of IFRC guidelines [46,47] as well as the Better Shelter proposals [9]; when relevant to understand the possible space of action of structural-related knowledge, more information on specific themes was gathered from other institutional reports and related research outputs. To understand the relevance of the finding, the theoretical coding was conducted by comparing the identified categories with the indicators emerging in the sustainability housing research [37].

4. The Structural-Related Challenges

4.1. The Representative Case Studies

The list of representative case studies is here reproduced together with highlights from the Kesselring matrix for ease of understanding of the structural-related issues. The list comprises temporary, transitional, and permanent housing as defined in Section 2 (Figure 4). The list has been developed according to procedures elaborated under Section 3.3, thus comprising a few examples from pilot studies (case studies represented in Figures 6e, 7b and 8f) and emergency responses in regions other than the Global South (Figure 6b,g and Figure 8a,c,e).

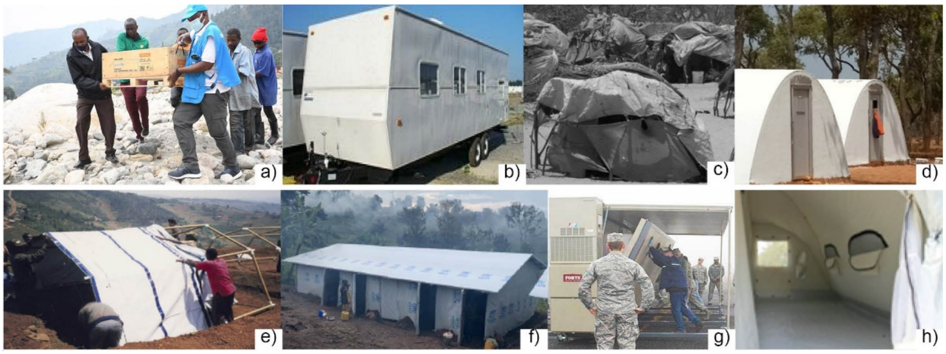


Figure 6. Selected temporary shelters. (**a**) High Performance Tent, UNICEF (© UNICEF/UN0588296 /Wamala) [48]; (**b**) FEMA trailer, US agency [42,49]; (**c**) Makeshift Shelter2, refugees in Chad, 2017 [39,50]; (**d**) Lifeshelter, Jens O. Olsson [51,52]; (**e**) Bamboo tent, Shigeru Ban architect, Rwanda, 1999 (© Shigeru Ban architect) [53]; (**f**) Shelters for the Ituri crisis, ShelterCluster, Dem. Rep. Congo, 2017 and outward (©Anja Pirjevec) [39]; (**g**) Deployable truck, Forts [54]; (**h**) Self-standing family tent, ShelterCluster [55].

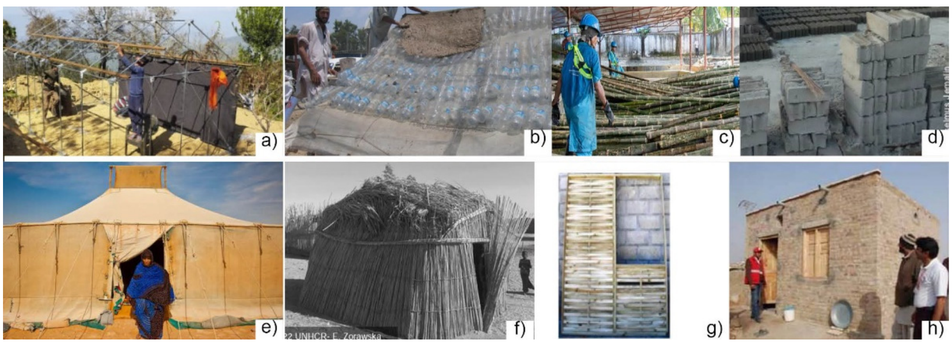


Figure 7. Selected transitional shelters. (**a**) RHU, UNHCR and Better Shelter (© Better Shelter) [55,56]; (**b**) Emergency prolongation in Pakistan, Shah et al., 2020 [57]; (**c**) Rohingya crisis, Shelter Cluster, Bangladesh, 2017 (© Nate Webb) [39]; (**d**) Indonesia earthquake, Shelter Cluster 2018–2020 (@Anselmus Jemalin) [39]; (**e**) Sahrawi refugees' camp, Tuaregs and Shelter Cluster [55]; (**f**) Emergency prolongation in Chad, Shelter Cluster, 2022 (©2022 UNHCR- E.Zorawska) [39,50]; (**g**) T-Shelter, IFRC, Haiti, 2010 [46,58]; (**h**) One Room Shelter, UNHCR, Pakistan, 2010 [46,59].

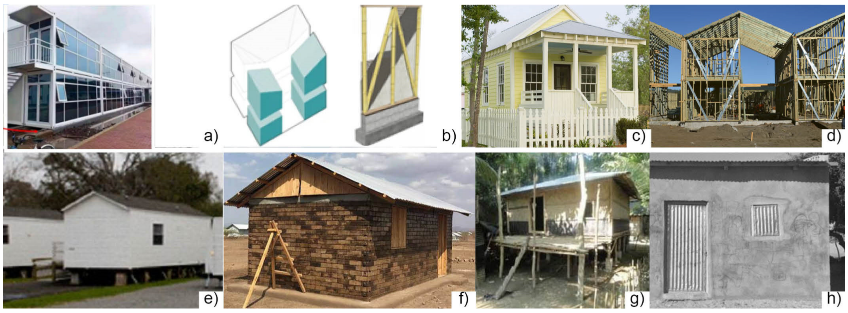


Figure 8. Selected permanent shelters. (**a**) Huoshenshan Hospital, the Chinese government, China, 2020 [60]; (**b**) NovaVida pilot barbaresque project in Ecuador [61]; (**c**) Katrina hurricane's Cottage in the US, Marianne Cusato (©Marianne Cusato) [49,62]; (**d**) Villa Verde in Chile, Elemental (© Cristian Martinez) [63]; (**e**) Building America Structural Insulated Panel (BASIP), FEMA [49,62]; (**f**) Turkana houses prototypes in Kenya, Shigeru Ban architects (© United Nations Human Settlements Programme, 2020) [64]; (**g**) Bandarban for recurring flood in Bangladesh, machan model [23,65]; (**h**) Emergency prolongation in Chad; Shelter Cluster (©2022 UNHCR-E. Zorawska) [39,50].

The matrix, as shown in Figure 9, shows shelters in rows and structurally related indicators in columns. Darker green colour shades indicate compliance with the indicator's criteria, and darker orange colours indicate non-compliance. Gray indicates an area with insufficient information. It is important to note that the matrix cannot be used to compare case studies, but rather to give a graphical representation of critical areas. The depicted shelters also showcase the variety of structural typologies within the vertical structure.

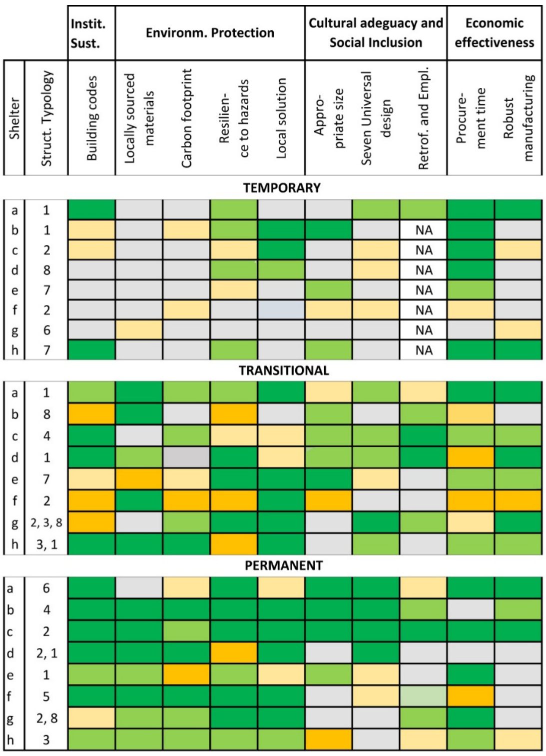
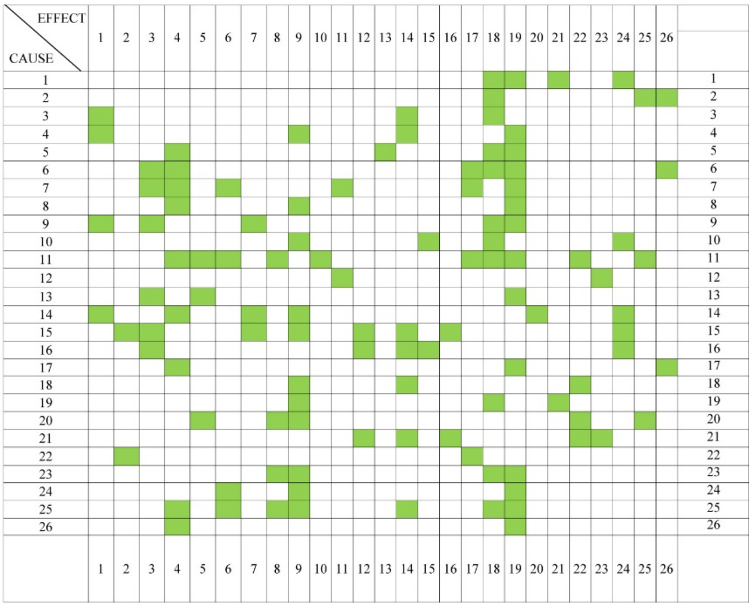


Figure 9. Highlights from the Kesselring matrix used within the categorization process. Letters refer to the case studies in Figures 6–8 and numbers refer to the structural typology, which reads (1) steel, (2) timber, (3) masonry, (4) bamboo, (5) adobe, (6) container, (7) tent, and (8) others. Darker green colour shades indicate compliance with the indicator's criteria, and darker orange colours indicate non-compliance. Gray indicates an area with insufficient information.

4.2. Codes and Categories: Issues and Challenges

This section summarizes the results of the coding and categorization process: it provides an overview of current strategies and guidelines to address the structure-related issues that emerged from the analysis and presents the challenges in their implementation. A variety of challenges were identified during the process. It was necessary to understand whether structurally related research might contribute to solving them. To reach the objective, the challenges were categorized and their relationship analyzed through an interrelationship method [36]. Figure 10 illustrates the interrelationship matrix, where the "i" rows and "j" columns report each of the 26 identified challenges, read respectively as a cause or as an effect. Coloured cells in the matrix mark the connections between the two lists. A high negative value of $\Delta = \left(\sum_{i=1}^{26} ij - \sum_{j=1}^{26} ij\right)$ characterizes a challenge that tends to be a consequence of other challenges.



CATEGORY	$\sum_{i=1}^{26} ij$	$\sum_{j=1}^{26} ij$	Δ
1 No land rights	4	5	−1
2 Does not fit users' culture	3	4	−1
3 No local income	3	9	−6
4 Low durability	4	9	−5
5 Unknown structural performance	4	3	1
6 No quality control	6	4	2
7 No training of workers	6	3	3
8 No fire safety	3	4	−1
9 Does not fit post emergency site planning	5	11	−6
10 Depleting local resources	4	1	3
11 Forced DIY	10	2	8
12 Long material provision time	2	3	−1
13 Technology needs testing	3	1	2

CATEGORY	$\sum_{i=1}^{26} ij$	$\sum_{j=1}^{26} ij$	Δ
14 Host country does not find it advantageous	6	7	−1
15 Imported technology specific of emergency	8	2	6
16 No local production facilities	5	2	3
17 Poor construction quality	3	4	−1
18 Not a good cost/ performance balance	3	11	−8
19 Do and do it again	3	14	−11
20 No structural assesment procedures	5	21	−16
21 Discontinued founds	5	23	−18
22 No shared knowledge with contractors	2	26	−24
23 Need for macro−planning of the camp	4	25	−21
24 Low long−term engagement of authorities	3	29	−26
25 Local hazard	7	28	−21
26 Need for ongoing maintenance	2	29	−27

Figure 10. The interrelationship matrix (above) and the chart (below) of 26 identified categories. The numbers in the matrix identify the 26 categories described in the chart. The existence of a direct relationship between the categories is expressed by a coloured cell in the matrix and computed in the chart.

The structure-related categories of emergency shelters are reported here with reference to the representative case studies from Section 4.1 (listed under Figures 6–8) and are grouped according to the relevant sustainability areas as defined in [37] and shown in Figure 11.

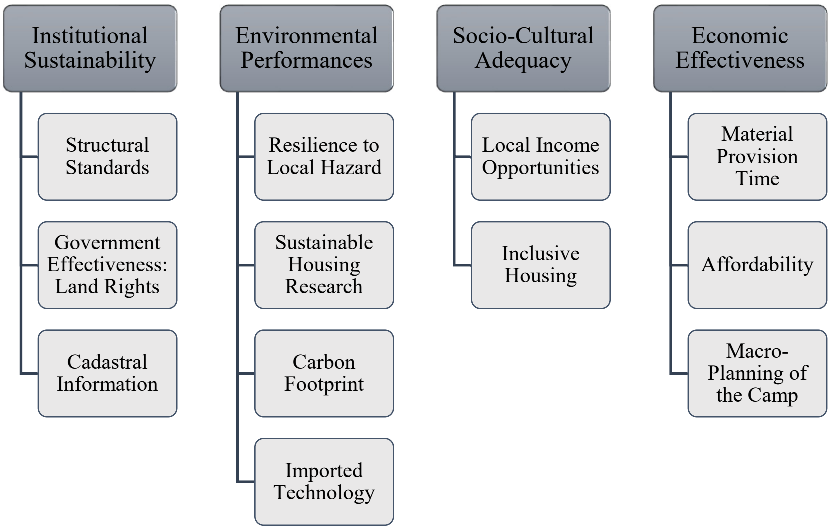


Figure 11. Categories: The structure-related issues and challenges.

4.2.1. Institutional Sustainability

Structural Standards: Procedures, Tests, and Products

Structural requirements for temporary housing are tendentially set lower than those for permanent housing. There are no set structural standards available specifically for short-term shelter categories, and the national standards which are used for long-term shelters are not applicable in such cases considering design, cost, and material wastage. To address this concern, the recent UNHCR sustainability assessment criteria [45] set a pass/fail procedure based on a content-related risk approach earlier developed in the IFRC guidelines [46]. In terms of construction materials, imported solutions can offer certified standards. Meanwhile, the usage of local solutions is generally considered more sustainable than imported solutions. However, if local solutions are not tested, the agency cannot be accountable for the structural integrity. Testing off-site full-scale prototypes designed using local structural typologies is not enough to guarantee the performance of the prototype once it is constructed on-site with the local material, typical timber, as shown in Figure 7g [46,58]. Researchers can support the testing and improvement of local materials and/or construction solutions and help develop procedures to conduct them, as shown in Figure 8g [23,65], but currently, their involvement in this area is noticeably sparse.

IFRC stresses that volunteers and the refugees themselves construct/reconstruct most of the shelters that are not meant to be permanent houses (including temporary restoration of damaged shelters) [14]. Their lack of knowledge in the construction of the emergency shelter and retrofitting can lead to very unsafe living conditions. Say for example, in the case of masonry shelters, see Figure 7h [46,59], unsupported openings may increase the effect of seismic actions on the shelter. Further, in the cases of wooden shelters, the unplanned increase in dimension or adding material in such a way as to create fire hazards (Figure 8d) [63], or repurposing lateral wind bracing to other usages (Figure 7c) [39] are among the identified threads. Thus, international agencies acknowledge the need to involve these actors and local workers in relevant training processes [10]. Though in addition to that, in [39,46] it has been noted that in some cases, discontinued technical support for retrofit due to funds has also led to unsafe modifications. Guidelines produced by NGOs [14,46] currently tend to overlook the need for renovation and maintenance and just partially discuss strategies and plans for covering these associated risks.

Government Effectiveness: Land Rights

In cases where adequate legal land rights are not granted, the local authorities may not permit the use of durable permanent shelters and strong foundations. This will lead to potentially lengthy negotiations. Due to bamboo's low durability, the authorities allowed the use of bamboo structures as shown in Figure 7c [39]. Setting up a treatment factory eventually increased its life span, though. In recent years there has been a surge in the use of lightweight demountable and reusable steel construction solutions which are well researched, tested, and guaranteed for long-term performance, one shown in Figure 8a [60], but funding limitation plays an important role in adopting such solutions. The need for use of local materials and local fabrication is a major concern not just in terms of temporary emergency shelters but also plays a key role in building construction regulations, as a part of reducing environmental impact or carbon footprint due to construction. Unlike other temporary shelters, in medical emergency shelters, a flat, rigid floor and ramps are necessary for accessibility and medical care [47] but these are more difficult to be implemented in such circumstances where temporary structures with unstable foundations are advised.

Cadastral Information

Emergency shelter solutions which comprise a set of alternative designs or sizes can fit the diverse family compositions, cultural habits, and sites located in urban or suburban settlements. In the case of Figure 8c [49,62], a shelter design developed and assessed for a hurricane eventually entered the permanent US housing market of tiny houses. However, transitional shelters are often associated with uncertainties about the future of the refugees and of the settlement's site, which adds to time-bounded funds. Hence, it is mandatory to study the actual timeline of the recovery process considering the affected populations' socio-economic and local environmental situations before assisting/providing the refugees with specific shelter solutions.

4.2.2. Environmental Performances

Resilience to Local Hazard

Providing the right shelter for a specific type of emergency (war, earthquake, and so on) is not a major structural design-related challenge, but the settlement sites where the shelters are provided should be free of future/unexpected hazards (vandalism, flood, storm, etc.). Past studies have reported cases where refugees are granted emergency settlements in areas prone to local hazards [46]. Most research concepts or innovations suggested in architectural engineering designs of emergency shelters are developed without full guidance on the specific local requirements and desiderata [17] (see Figure 6e). UNHCR and IFRC's guidelines suggest addressing the risk of flood including fluvial/river floods. IFRC also has suggested considering the risk of fire due to context. Fire risk comprises risk of wildfire in the site as well as the presence of fire in the shelter for cooking or heating. UNHCR recently moved toward long-lasting solutions and stressed site planning prevention measures, comprising an ideal distance between structures. It further introduced an evaluation of the percentage of fire-resistant, retardant, and flammable material. However, fire-retardant material is easier to be accomplished in outsourced temporary shelters, as shown in Figure 6, but rarely in transitional shelters, as shown in Figure 7. The provision of emergency settlements after an earthquake most often happens in the vicinity of the affected area, itself a disaster-prone zone; it is mandatory to ensure that the structures are designed to either withstand the seismic load from aftershocks or avoid injury to their occupants (in case of a collapse). The latest research on earthquake-resistant techniques has shown proven efficiency and viability of solutions for reducing seismic vulnerability [66,67] yet they are disconnected from guidelines in the sector and field implementations thereof. Moreover, empowering refugees has been enlightening on the need for privacy to ensure their security (see Figure 6e). On a case base, this may require an opaque, strong exterior wall/cladding to protect the occupants from vandalism. In the case of Figure 7f, studies report that this happened in the form of knife attacks through the exterior wall [39,57].

Existence of Sustainable Housing Research

Through its sustainability criteria [45], UNHCR explicitly aims to assist the NGOs and the host governments in the evaluation of emergency housing solutions. Sustainability is meant to be achieved by providing resilient shelters that are safe, energy-efficient, low-cost, and use local renewable or recycled materials for their construction without burdening natural resources. It is worth noting that the need for thermal insulation, natural light, and ventilation is considered satisfied when certain windows-to-volume ratio and indoor temperature targets are met. No mention is paid to best practices, and such, reports neglect a discussion of passive solutions that may leverage the form or materiality of the structure. NGOs strive to implement resilience strategies, but their limited political power in the affected areas means that agencies tend to favour incremental innovation in existing solutions, whose impact they can more easily measure in the short term, potentially hindering innovative approaches' access to the settlements [11]. Maintenance is easier if the shelter's construction and operation/maintenance technology fit the local practices of the host community or the displaced population. However, local typologies may have been lacking adequate research and development. For example, the shelter of Figure 7h [46,59] is made of fired bricks, and, despite adobe being suggested as a potentially more environmentally sustainable alternative, the option is currently dismissed due to a lack of favourable, measured performances.

Carbon Footprint

In light of recent attention towards the climate crisis, carbon footprint reduction, which measures the reduction in the environmental impact of construction, has risen to a peak concern in the design and construction of buildings. Countries around the world are racing to reach NetZero carbon targets [17,22]. In terms of emergency shelters, to achieve carbon reduction using local materials, common practices have led to a depletion of local resources, typically deforestation, and increased risk of erosion. The risk of deforestation is so high that the UNHCR guidelines set it as the biggest concern [45]. Areas of harsh environmental conditions tend to lead to cycles of construction and reconstruction as in the case of wood and timber shelters as shown in Figures 6c and 7f, which, until not addressed, see Figure 8h, accelerated desertification, and threatened groundwater and natural habitats [39]. In-depth research on local materials for housing available in risk-prone scenarios shall be conducted, also considering the sustainable usage of the resource according to forecast scenarios. A load-bearing structure can have a significant impact on thermal regulation. A more integrated approach has been applied to the design of outsourced, ready-made solutions (Figure 6a,h) [48,55]. Meanwhile, researchers independently developing solutions with locally available resources and materials may focus on aspects under their area of expertise lacking broader considerations, see Figure 7b. Unfortunately, these overlooked current impacts might lead to unfavourable and unfixable consequences.

Imported Technology

Imported technologies specific to a certain emergency can be lifesaving when a high, sudden demand for shelters cannot be satisfied by the local market, assuming this is still on hold. In [68], it was statistically found that a 10–20% range of imported elements within a technology tends to gain the best speed/cost of wall ratio, measured as (person $\times$ day/m^2)/($/m^2 wall). Yet imported elements may not be adaptable to the specific environment, as in the case of the structural and insulating panels shown in Figure 6d. A series of solutions that leverage building information modelling (BIM) has been envisioned or implemented within the structural engineering research and industry following the COVID-19 pandemic, as shown in Figure 8a, primarily in the areas of modular and prefabricated buildings. For temporary shelters in underdeveloped countries, UNHCR, leveraging on the partnership with NGOs, has been able to set a series of stringent requirements and desiderata ranging from transportability to structural performances to characteristics factoring toward a short procurement time and adaptability to multiple emergency scenarios [40]. This has allowed large industries to enter the scene and favour innovation, as in the case of Ikea supporting the RHU shelter depicted in Figure 7a [55,56]. In terms of transitional shelters, because of the interaction between local and global stakeholders, information about requirements and the evaluation process is more open and at the same time blurrier. For example, solutions are developed for a niche market, with the trailer for wildfire guards depicted in Figure 6g.

4.2.3. Socio-Cultural Adequacy

Local Income Opportunities

Under the resilience goals, the construction process of the shelter and the shelter itself shall increase the earning possibilities of the refugees [69]. Typical solutions that NGOs try to implement are training the refugees in workmanship while constructing the shelter or designing the shelter so that it can host small activities or livestock. If the condition of the refugee improves, the refugee can then sell or rent the shelter, or recycle/reuse its material [69]. The introduction of long-lasting, imported solutions that perform well for the local site may favour local employment if it allows the locals and/or the refugees to develop skills for processing and/or installing the technology; this was for example the case of the light gauge steel frames and silica boards in Figure 7d, which were integrated with the locally produced concrete blocks. Local social habits, however, may require effort for involving women willing to take part in training and construction processes, as in the case of Figure 8h. The most common shelters are lightweight, low-rise buildings, limiting the creation of a potentially more resilient settlement than those under development in the case of Figure 8b [61]. On the other hand, the commonly used bamboo and timber structures require maintenance, and such implies that the users are financially able and/or willing to do so [70]. For the solution to be more viable and advantageous to the host community, the settlement projects have considered the involvement of local contractors [71]. Informed architects can help develop pilot shelters caring about the local material culture, both in visual and functional aspects, for example, the production of compressed earth blocks in the case of Figure 8f. However, local communities may not be ready for large productions, as in the case of Figure 7f, and there may be a lack of local production facilities in terms of capital, technology, and material and human resources.

Inclusive Housing

Cultural adequacy is a desideratum known to improve the psychological well-being of refugees [72], which can speed up the recovery process. Failing to achieve it may lead to unviable solutions, as in the case of Figure 8e, which is efficient under energy consumption, yet is culturally no more adequate. However, it is not clear how the structure contributes to cultural adequacy. Imported containers have been demonstrated to lengthen the psychological recovery process versus traditional, indigenous solutions [39], but they have also been welcomed outside the emergencies when mediated by striking architectural designs. In one of the Tuaregs camps, see Figure 7e, the Tuaregs welcomed the more performative imported canvas and ropes to construct their traditional tent, and their solution was eventually adapted and inserted by UNHCR in their shelters' catalog [56]. These findings seem to suggest that empowered local communities and stakeholders may help to reach innovation beneficial to a larger community. When the sheltering is protracted, disregarding serviceability can generate strong user dissatisfaction, as in the case of Figure 7c, due to a lack of stiffness under wind load [39]. Communities that recover housing habits tend to have higher expectations from temporary and transitional housing [28,49], see Figure 8e.

4.2.4. Economic Effectiveness

Material Provision Time

IFRC currently sets a 3W (Who does, What, and Where) system timeframe for the successful delivery of transitional shelter to the affected sites. However, even basic items like tarpaulin for tents have often been subjected to significant delivery delays during emergencies, as reported in the case of Figure 6f and others, leading to makeshift solutions, see Figure 6c. In [68], it is found that the construction of the roof, which is typically a timber frame to be assembled on site, lengthens the construction time of the shelters.

Affordability

UNHFRC proposes an affordability score [45] measured as the cost, from fabrication to delivery and installation, divided by the shelter life span in years and by the area in meter squares. The cost of materials during an emergency can substantially increase, especially the internationally procured ones. Here the choice of ideal material for emergency housing plays a key role. The material adopted in the design of an emergency solution, given that right after an emergency there will be a lack of resources, should be in reach to the settlement and be abundantly available ensuring reduced cost in procurement.

Macro-Planning of the Camp

Proper initial research and planning are essential in the design of large-scale emergency settlements, and this is mandatory specifically in terms of transitional and permanent shelters. Ensuring fire safety distances and escape routes after construction may lead to increased costs, as in the permanent solution of Figure 8d [63]. The demand-based nature of sheltering tends to produce uncontrolled emergency settlements and exacerbate the risk. In terms of shelter size, provision of the $A = 3.5\ m^2$ minimum area per person and a minimum height $h = 2.2$ m in a cold climate and $A = 4.5\ m^2$, $h = 2$ m in a hot climate are target values based upon factors such as time spent indoor and usage pattern [9]. It is important to note, however, that the size-based approach is incremental and depends on the situation where the shelters will be placed. Competition with permanent houses nearby, as in the case of Figure 7f, even more so in the case of urban settlements, see Figure 7c, may lead to diminishing them.

5. Theoretical Coding: Results

Due to the research method applied, the propositions are diverse. Broad results were obtained while developing this part of the research, thanks to the comparison made between the categories identified in this paper and the sustainable housing indicators expressed in [37] and derived from the Geneva Charter [6]. The comparison revealed how addressing challenges within the emergency housing process is functional to reach the possibility to address the ones expressed by the sustainable housing framework. This is represented in Figure 12, where arrows show the links among the categories identified in this paper and the reference indicators. Concerning the specific contributions to the areas of the sustainability framework, whereas the propositions in the institutional and socio-cultural area highlight research gaps, the ones addressing environmental efficiency open for discussion to the opportunity to strengthen certain areas of investigation or to insert the emergency housing process among their application fields. The propositions have no aim to be exhaustive or definitive. Indeed, many performances that are assumed as must-be in permanent housing have been reached in the sheltering process through experimentation. Whereas the structural performances are now requirements (must-be), other performances are set as one-dimensional or desirable targets.

Within the Institutional Area

Whereas the standardization process is ongoing, the exigencies of the emergency sector may not be fully envisioned. There is a discrepancy between the quality certification offered by imported technologies and the structural assessment procedures, quality control execution, and tests that are on average implemented with locally developed/used solutions.

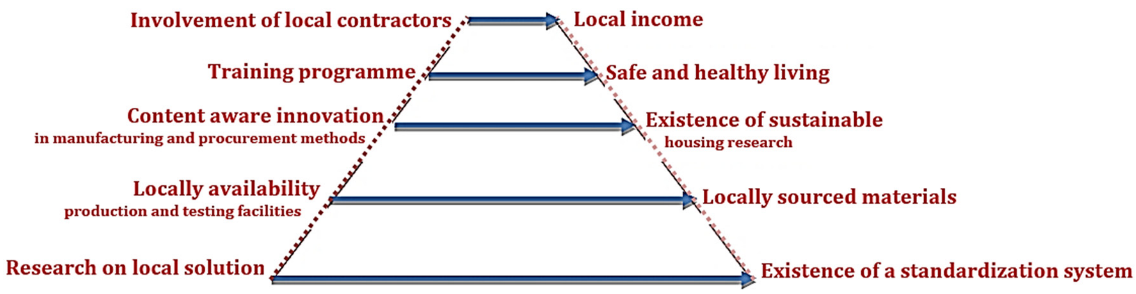


Figure 12. Links among the categories identified in this study and the sustainability indicators.

Within the Environmental Efficiency Area

Given the importance of speed in the emergency response, the research shall assess local technologies in risk-prone scenarios regardless of the presence of a disaster. The assessment could cover the structural and environmental performances as well as the cultural value of the technology. If the assessment demonstrates that a solution is promising to minimize the depletion of natural resources, it may further address the possibility to bring it up to higher standards by the usage of advanced manufacturing (for example, 3D printing of custom molds or joints) that can be employed locally. As relevant, international educational and research collaborations may be set involving suitable local stakeholders and institutes to map [73] and support innovation in vernacular technology. Pilot studies dealing with passive survivability may address areas that may become at risk of a hazard in the future, to the advantage of the local government and research.

1. The usage of imported material, typically steel, could be limited to a few key elements to increase the structural performance of the system, namely stability and serviceability. In best practices that emerged from the case studies, corner half–steel columns [20], and diagonal stiffeners and bracings were employed [63].
2. To help fight deforestation, suitable roofs could be thought that limit the usage of wood either with local or imported technologies. The design of the elements and their joints may be such to avoid the misplacement of the element and be aware of locally feasible installation techniques. This research field may overlap with architectural engineering research on design for disassembly and recycling.
3. Research in the field of structural refurbishment could support NGOs in the elaboration of allowable modifications within a certain technology or by providing exemplification of alternative designs based on modular applications which might allow safe modifications to be executed under typical scenarios.

Within the Economic Effectiveness

Readymade solutions whose technology cannot be integrated/adapted later to the local production possibilities are to be evaluated considering the return on investment. This measures both the delivery time, thus reading for transportability, and the cost over the lifetime of the shelter, thus addressing robust manufacturing and adaptability. Whereas it is possible and sometimes necessary to design shelters in a way to be particularly convenient to address special functions, the transient nature of the sheltering requires that the design shall consider the possible relocation. For example, during the recent COVID pandemic there was a scarcity in supplying emergency shelters that suit medical requirements, but, after the emergency, often the provided shelters were left unused.

Within the Socio-Cultural Appropriateness

The study found that it is not clear what the role of the structural typology and materiality is in the creation of shared material culture and characteristic structural forms of emergency sheltering settlements. Available data mainly cover the usage of non-structural materials and suggest that exotic, non-structural materials initially suffer from a stigmatized poor quality, but they are accepted by the users when the hypothesis is proved wrong.

6. Conclusions

Natural and human-made disasters strike nations all over the world, frequently resulting in massive home losses. By the Geneva Charter, the goal of the emergency housing process is a permanent housing solution. Therefore, it shall align with the goals of sustainable housing. Even more so given the growing dimensions of the sector. Considering the variety of scenarios, international agencies propose resilience strategies and cash support to cope with the emergency. In many countries, however, housing policies are still under development, while refugee conditions are precarious. Considering that the structure is the most durable element in construction, this paper has analyzed the emergency process to highlight structural issues, identify areas that need further investigation, and propose research directions. Several key issues related to institutional sustainability, environmental performance, sociocultural adequacy, and economic efficiency were captured thanks to the usage of a multiple-case study approach. All these factors make it more likely that structures aimed at emergency response will end up in the direction opposite to sustainable housing. The lack of sustainable performance of post-disaster housing during recovery, rehabilitation, and reconstruction primarily result from the lag between the emergency and reconstruction phases caused by unattended socio-economic issues, as well as from the implementation of environmental and economically unsound solutions. Sheltering is part of the construction sector and as such, it is expected to favor local employment and target cleaner production. Shelters whose structure is not durable and resilient or adaptable will need to be demolished and often rebuilt. This will add to the carbon footprint of constructions in exchange for temporary benefits. The study targeted countries in Africa and Asia. In many developing countries, the construction sector employs technologies that tend to be outdated elsewhere. Sheltering can be considered an opportunity to develop sustainable housing processes that ask at small scales whether local resources can be leveraged to meet climate change challenges. Few case studies demonstrated that problem statements within the sustainable housing framework could be formulated that read for the challenges posed by the emergency sector. Building upon the best practices within the temporary sheltering solutions, frameworks could be established to filter and develop products, processes, and technological innovations, that can leverage on and boost local expertise in the long term. Of course, the effectiveness of the formulated problems and solutions shall be judged in practice, which ultimately led to the need for cooperation and coordination in and beyond academia.

A major contribution of this paper has been to bring attention to the studies conducted by global agencies and field actors that are the primary font of information on the field, yet with limited links to structural-related research. It is encouraged that the proposals be read with consideration of the incremental nature of innovation in the shelter technical area. This requires time to identify desirable, feasible, and viable aspects, develop solutions, and set metrics.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/buildings13010032/s1, File S1: The full list of shelters analyzed, and temporary coding. References [74–118] are cited in the Supplementary Material.

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