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DEVELOPING A DECISION SUPPORT SYSTEM FOR POST-DISASTER TEMPORARY HOUSING IN IRAN

A THESIS PRESENTED IN PARTIAL FULFILMENT OF THE
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Abstract

Natural disasters disrupt societies by destroying homes and displacing millions, exacerbating vulnerabilities and deepening socioeconomic disparities. Post-disaster housing recovery is a critical component of disaster management, progressing through the stages of emergency sheltering, temporary housing, and permanent housing. Temporary housing plays a pivotal role in providing displaced populations with a transitional safe haven; however, its implementation presents significant challenges, including high costs, delays in permanent housing, and suboptimal sustainability. This research addresses these complexities by developing a decision support system (DSS) tailored for post-disaster temporary housing in Iran.

The research problem is defined clearly in the second section of Chapter 1 as the critical problem of post-disaster temporary housing in Iran and the lack of a reliable decision support system for the decision-makers to determine the model of housing recovery. The following section (1.3) defines the aim of the research to improve decision-making processes related to post-disaster temporary housing in Iran, and in this regard, six questions are designed and listed in Table 1.1.

To address the research questions, 9 research objectives are defined, which are used to achieve the research aim in a step-by-step approach. The ultimate objective is to enhance decision-making processes for temporary housing by developing a novel decision-support system and integrating diverse factors such as sustainability, timeliness, cost-effectiveness, cultural compatibility, and technological feasibility. The research employs a multi-methodological approach: a critical literature review identifies research gaps within both global and Iranian contexts; case studies from seven disasters in Iran between 2003 and 2023 provide empirical insights; and a novel DSS framework is developed using Multi-Criteria Decision-Making (MCDM) methods.

Primary findings indicate that decision-making for temporary housing is not purely technical but deeply interconnected with social, cultural, and environmental dimensions. Sustainability emerges as a crucial criterion, with strategies such as modular prefabrication, 3D printing, rapid construction technologies and innovative structural systems demonstrating the potential to reduce construction time, costs, and environmental impact. However, contextual considerations, including local resource availability and cultural acceptance, remain essential for successful implementation.

Further findings clearly show the significance of the decisions made about the housing recovery model, their effects on the displaced people, and the need for a reliable DSS to assist the decision-makers in this regard. The ultimate finding of this research is the DSS, developed and validated in Chapter 6, which is based on the data produced in the previous chapters and the comprehensive literature review conducted to achieve the first seven research objectives. This finding directly addresses the research problem by improving the post-disaster temporary housing process in Iran by enhancing the decision-making process.

The data used for developing this research was collected from multiple sources. The first-hand data was collected from various stakeholders, including the users (displaced people), the experts from national and governmental departments, and industry. The second-hand data was used for studying the recent post-disaster recovery processes. Finally, the model was validated by two series of qualitative data collected from industry experts using interviews and focus group methods. More details about the model and validation are explained in chapter 6.

This research contributes to disaster management by proposing a structured, evidence-based framework to assist decision-makers in selecting appropriate temporary housing strategies. By addressing gaps in the existing literature and emphasizing user-centred and sustainability-focused approaches, the study advances understanding and practices in post-disaster recovery. The DSS

framework, validated through expert feedback, provides practical guidance for deploying temporary housing in Iran and comparable contexts, aiming to balance immediate relief needs with long-term recovery objectives.

Additionally, the study underscores broader implications for global disaster management, advocating for resilient, adaptable, and inclusive reconstruction practices. The framework and methodology used in developing the DSS can be customised and utilised for similar post-disaster recovery processes in developing countries with common conditions and contribute to addressing the worldwide shelter problems.

Future research should refine the DSS, explore its application across diverse contexts, and further develop sustainable reconstruction technologies. These findings contribute to fostering disaster-resilient societies, ensuring equitable recovery, and mitigating the cascading impacts of displacement.

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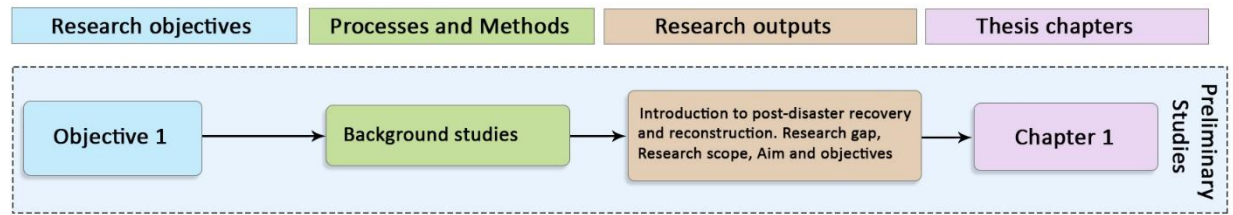
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Abbreviations

AC	Air Conditioning
AHP	Analytical Hierarchy Process
AI	Artificial Intelligence
BIM	Building Information Modelling
BREEAM	Building Research Establishment Environmental Assessment Method
CO ₂	Carbon Dioxide
EU	European Union
GHG	Greenhouse Gas
GRID	Global Report on Internal Displacement
HFI	Housing Foundation of Iran
HVAC	Heating, Ventilation, and Air Conditioning
IDP	Internally Displaced People
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change

MEP	Mechanical, Electrical, and Plumbing
NDMO	National Disaster Management Organization
NGO	Non-Governmental Organisation
NZ	New Zealand
SBE	School of Built Environment
UN	United Nations

1 Chapter 1: Introduction



1.1 Research background

United Nations (UN) defines a disaster as “a situation or event, which overwhelms local capacity, necessitating a request to the national or international level for external assistance; an unforeseen and often sudden event that causes great damage, destruction and human suffering.” Natural disasters, including earthquakes, floods, hurricanes, and wildfires, have devastating effects on communities, particularly through the loss of homes and displacement of families. According to the 2024 Global Report on Internal Displacement (GRID), during the year 2023, 46.9 million people were forced to leave their homes due to disasters and conflicts, with 26.4 million displaced specifically because of disasters. Also, by the end of 2023, a total number of 76.9 million people were displaced internally, which has doubled in the past 10 years (IDMC, 2024). Figure 1.1 shows the global distribution of IDPs.

The destruction of homes not only results in immediate physical harm but also leads to long-term psychological, social, and economic consequences (Johnson, 2008). According to Cutter et al. (2014), the impact of natural disasters on housing infrastructure significantly influences the speed and efficacy of community recovery, as homes represent not only shelter but also a cornerstone of familial and social networks. The loss of homes during a disaster exacerbates vulnerability, as

individuals are left without a secure base to organise recovery efforts, further delaying rehabilitation and deepening socioeconomic disparities.

The importance of post-disaster recovery and reconstruction cannot be overstated. Recovery, as explained by Kates et al. (2006), is a multidimensional process that encompasses not only rebuilding physical structures but also restoring social, economic, and environmental well-being. Reconstruction of homes serves as a critical phase in this process, offering both tangible and symbolic restoration of normalcy for affected populations. Research indicates that successful reconstruction projects are those that incorporate community participation, as local knowledge can inform more resilient and adaptive rebuilding practices (Alexander, 2002). Moreover, effective recovery efforts require sustained financial support and coordination between governmental, non-governmental, and international organisations to ensure equitable distribution of resources (Davis & Alexander, 2015).

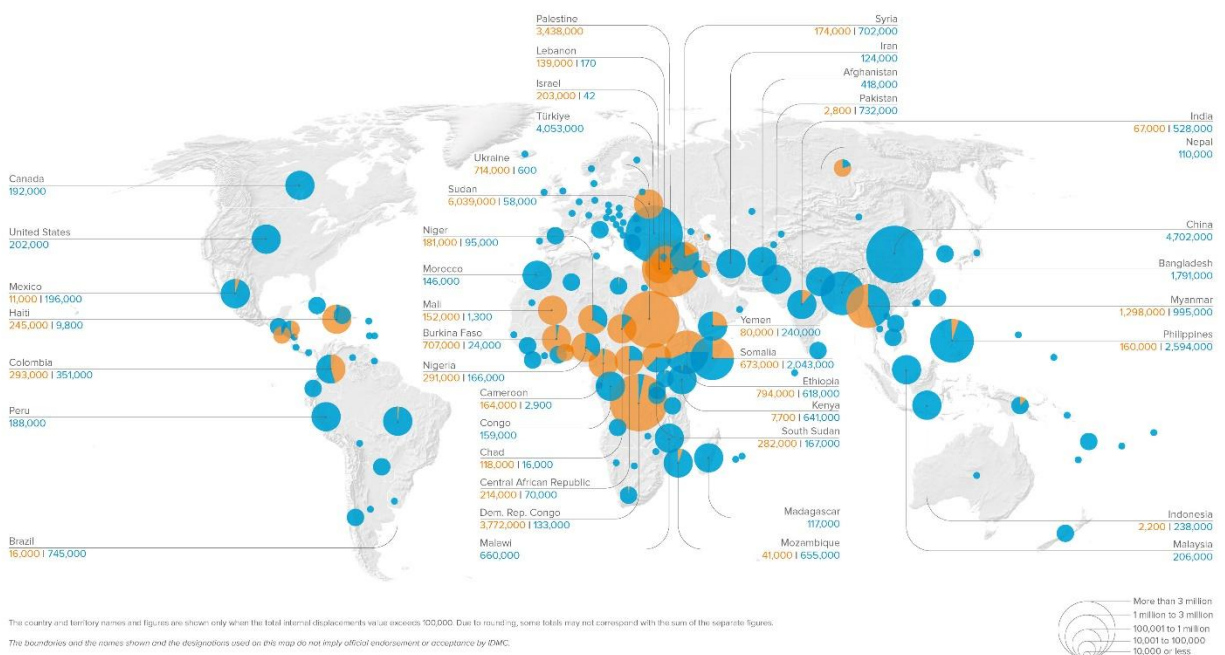


Figure 1.1. Global distribution of internally displaced people by conflicts and disasters.

Source: IDMC (2024)

As a result of increasing disaster frequency and intensity due to climate change, there is growing recognition of the need for resilience in recovery and reconstruction practices. The "Sendai framework for disaster risk reduction 2015–2030" (2015) advocates for "building back better," emphasising the integration of risk reduction measures into post-disaster recovery to enhance future resilience. Studies, such as those by Mannakkara et al. (2018), have shown that communities that rebuild with stronger, more sustainable housing structures are better able to withstand subsequent disasters. Therefore, investing in resilient reconstruction not only addresses immediate housing needs but also plays a pivotal role in long-term disaster preparedness and sustainability.

Housing recovery following disasters is a complex process that may take up to several years to complete. Successful reconstruction is a multifaceted process that involves restoring infrastructure, services, and communities while aiming to build back better and more resilient (Davis & Alexander, 2015; Mannakkara et al., 2018). There are four main stages in housing recovery after disasters: emergency sheltering, temporary sheltering, temporary housing, and permanent housing (Quarantelli, 1995).

The "emergency sheltering" stage occurs during the peak of the crisis and immediately afterwards. It involves short-term accommodations, such as plastic sheeting for protection, staying with neighbours, or large-scale shelters like stadiums or urban facilities initially built for emergencies, wars, or natural disasters. Following this, the "temporary sheltering" stage provides slightly more stable conditions but is still unsuitable for long-term habitation. Here, basic amenities may be available, yet accommodations remain transitional and do not support full daily living functions. In the "temporary housing" stage, families begin to regain a sense of normalcy and can resume daily routines, including work, school, food preparation, and social activities. This stage usually

involves accommodations like small, prefabricated houses or rented apartments, allowing families to rebuild their lives within a temporary yet functional space. Finally, "permanent housing" marks the completion of the recovery process. In this stage, families move into long-term housing solutions that replace or improve upon their pre-disaster homes, often incorporating resilience measures to better withstand future disasters. This stage aims to restore housing stability and quality of life for the affected community, providing them with secure, lasting homes (Quarantelli, 1995).

Among these four stages, the temporary housing stage is a critical component in the post-disaster reconstruction process, serving as an essential bridge between immediate emergency shelter and the establishment of permanent housing solutions. In the aftermath of disasters, a significant number of homes are often damaged or destroyed, leaving many individuals and families without adequate shelter. Temporary housing provides these displaced populations with essential living conditions that ensure dignity, privacy, and protection, enabling them to gradually resume their daily lives while permanent housing is being developed. This transitional phase is vital not only for meeting the basic needs of affected communities but also for supporting their psychological and social well-being during the recovery process (Félix et al., 2015).

However, the implementation of temporary housing presents several challenges that can impact the overall sustainability and effectiveness of post-disaster recovery efforts. Issues such as environmental impact, economic feasibility, and social integration must be carefully considered to avoid hindering the long-term resilience of affected communities. For instance, poorly planned temporary housing can lead to environmental degradation, economic inefficiencies, and social isolation. Therefore, where using temporary houses is inevitable, adopting a requirement-based design strategy that emphasizes sustainability is crucial. Such an approach ensures that temporary

housing solutions are environmentally responsible, economically viable, and socially acceptable, thereby enhancing the overall success of the reconstruction process (Montalbano & Santi, 2023).

1.2 The problem statement

The use of temporary housing following natural disasters is widely discussed in disaster management literature due to its implications for community recovery, especially in developing countries. Temporary houses provide a safe living space for displaced individuals, allowing them a transitional space while permanent structures are rebuilt or repaired (Johnson, 2007). These shelters are essential to prevent prolonged living in emergency shelters, which often leads to negative social, psychological, and economic effects. However, their implementation also faces critiques, particularly regarding high costs, limited longevity, and the potential to delay the construction of permanent housing (Johnson et al., 2006). Despite these critiques, temporary shelters often serve as a practical response to the immediate needs of disaster-affected populations.

In some cases, failure to provide temporary housing has led to severe consequences, including worsened health outcomes, increased vulnerability to subsequent disasters, and exacerbated socioeconomic disparities (Johnson et al., 2006; Schilderman, 2004). Post-disaster environments, particularly in countries with limited resources, require swift action to prevent these cascading effects. Without adequate shelter, affected populations face exposure to adverse weather conditions, unsanitary living environments, and, in some cases, forced migration, which can disrupt livelihoods and community cohesion (Lindell & Prater, 2003). Hence, the availability and timely deployment of temporary housing become critical in mitigating the broader social and economic fallout of natural disasters.

Informed decision-making on whether or not to deploy temporary housing is crucial for effective disaster management, and decision-makers must weigh various factors, including the timeliness,

economic, social, and environmental aspects of temporary housing solutions (Davis & Alexander, 2015; Khorshidian, 2023; Peacock et al., 2014). Without a structured decision-making framework, choices about temporary housing may rely on ad hoc measures that are not necessarily in the best interest of the affected community. This underscores the need for a systematic approach to evaluating both the short- and long-term impacts of temporary housing in the context of disaster recovery.

Despite the critical importance of this issue and examining the literature, there remains a notable lack of research focused specifically on the decision-making processes for implementing temporary housing in developing countries, particularly in Iran. Much of the existing research emphasises the design, effectiveness, and sustainability of temporary structures rather than the complexities of deciding when and how they should be used. Consequently, there is an urgent need for more studies that address the decision-making factors influencing temporary housing adoption, especially given the high stakes in terms of social stability and recovery timelines.

Therefore, the research problem of this thesis can be summarized in the lack of a systematic decision-making framework for determining whether to implement a temporary housing stage after disasters in Iran. This is a critical decision that directly affects the lives of displaced people and requires careful consideration of a wide range of parameters, as well as the application of contextual knowledge.

1.3 Research aims and objectives

Assessment of the research background and problem statement highlights a critical need to address the existing knowledge gap in the early-stage decision-making process for post-disaster housing recovery within the Iranian context. This thesis focuses on the contextual background, as well as the theoretical and practical concepts associated with this decision-making process. Furthermore,

it seeks to provide recommendations that enhance post-disaster recovery efforts within Iran's disaster management and reconstruction sector.

Developing a deeper understanding of these decision-making processes can contribute to more effective disaster response strategies and improve resilience in disaster-prone regions (Johnson & Lizarralde, 2012; Khorshidian & Fayazi, 2023). A comprehensive research approach could incorporate insights from various stakeholders, including government agencies, local communities, and NGOs, to build a comprehensive framework that guides temporary housing decisions. By addressing the existing research gaps, this thesis aims to inform policymakers on making evidence-based choices that balance immediate needs with long-term recovery goals in disaster-affected areas.

Therefore, the primary aim of this thesis is to improve decision-making processes related to post-disaster temporary housing in Iran by developing a reliable decision support system. To accomplish this, the following research questions and objectives have been formulated.

Table 1.1. Research questions and objectives

<i>Research questions</i>	<i>Research objectives</i>
<i>Q1: What are the latest international innovations and best practices in post-disaster temporary housing?</i>	<i>Objective 1: To identify post-disaster recovery processes, related theories and concepts.</i> <i>Objective 2: To examine, review, and compare the latest sheltering and temporary housing technologies.</i>
<i>Q2: How can post-disaster sheltering be achieved sustainably to avoid recreating future vulnerabilities?</i>	<i>Objective 3: To conduct a critical literature review on sustainability in reconstruction and temporary housing and the assessment methods.</i>
<i>Q3: Are the available decision support systems able to solve the specific decision-making problems of temporary housing in Iran?</i>	<i>Objective 4: To identify the latest post-disaster decision-making frameworks internationally and in similar countries and to examine if they include the specific problems identified in Iran.</i>

	<i>And, to study the decision-support systems and their usage in post-disaster context.</i>
<i>Q4: How do post-disaster temporary housing processes work in Iran?</i>	<i>Objective 5: To investigate and analyse the policies, processes and technologies used for post-disaster temporary housing in Iran in recent years.</i> <i>Objective 6: To evaluate the decisions made about temporary housing in the most important recent cases</i>
<i>Q5: What factors should be considered in the decision-making process?</i>	<i>Objective 7: To conduct an explorative case study to know the latest temporary housing solutions used in Iran and their characteristics from users' perspectives.</i> <i>Objective 8: To find the displaced people's priorities and the required parameters to be considered in the decision-making process.</i>
<i>Q6: How can a decision support system be developed to guide post-disaster temporary housing in Iran?</i>	<i>Objective 9: To develop and validate a novel decision support system based on the previous steps for supporting the decision-makers in selecting the appropriate housing recovery model</i>

This thesis consists of several research projects aiming to address the research objectives and propose a decision-support system based on the outcomes of all research. Figure 1.2 depicts the literature review process leading to the problem statement and the research objectives.

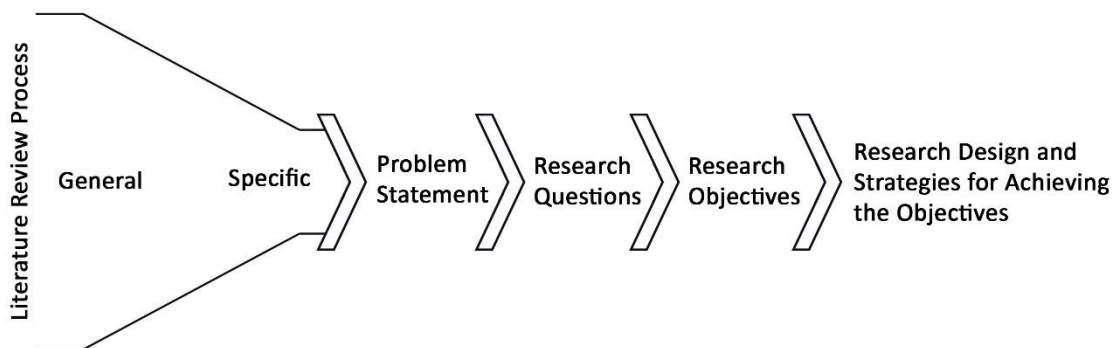


Figure 1.2. Literature review process leading to the research objectives.

1.4 Rationale and Significance

The rationale for this research lies in addressing the critical challenges associated with decision-making for temporary housing deployment after natural disasters, particularly in developing countries such as Iran. Temporary housing plays a pivotal role in disaster recovery by providing shelter, security, and a foundation for resuming daily activities. However, implementing temporary housing is a complex process that requires balancing immediate needs with long-term considerations, including costs, cultural suitability, and environmental impact (Johnson et al., 2006). The lack of a clear framework for making informed decisions often leads to inconsistent or ineffective solutions that can exacerbate the vulnerability of affected populations (Peacock et al., 2014). The case studies done in the chapter 4 of this thesis clearly shows the challenges of the current decision-making processes in Iran and the success and failure stories in planning for a smooth transition towards permanent housing. This study seeks to fill a crucial gap in understanding how these decisions should be made and the factors that influence them.

The significance of this research is amplified both by the catastrophic consequences of not using temporary housing when it is needed and by the negative effects of using it when alternative solutions are available. Without timely and appropriate shelter, disaster-affected communities face heightened risks, including exposure to extreme weather, unsanitary living conditions, and prolonged displacement. These conditions can lead to severe social, psychological, and economic impacts, undermining both immediate recovery efforts and long-term community resilience. However, temporary housing units are usually expensive and often criticised for their weak social and environmental performance (Lizarralde et al., 2010). By investigating the decision-making processes for temporary housing, this research aims to enhance the effectiveness of disaster

response strategies, ensuring that temporary housing interventions meet the needs of vulnerable populations while minimizing negative outcomes.

The novel and innovative approach of this thesis involves utilising a well-established and reliable decision-making method to address the critical issue of determining the housing recovery model—a topic with a long history of discussion in post-disaster reconstruction theories. This approach acknowledges and builds upon the extensive existing knowledge in post-disaster recovery and reconstruction while also incorporating insights gained from contextual research. By doing so, it aims to support decision-makers in making more informed and well-considered decisions. This study also contributes to the broader field of disaster management by addressing a notable gap in the existing literature. While considerable research has focused on the design, implementation, and evaluation of temporary housing, far less attention has been given to the decision-making frameworks that guide their use. By focusing on developing countries, especially Iran, this research highlights the unique challenges faced in resource-constrained environments, providing valuable insights for policymakers and practitioners. Ultimately, the findings aim to inform the development of a systematic approach to temporary housing decision-making, promoting evidence-based strategies that balance immediate relief with sustainable recovery goals.

1.5 Scope of the research

The research scope of this thesis centres on developing a decision support system tailored for post-disaster temporary housing in Iran. The main focus is on enhancing the decision-making process for the use of temporary houses, which underscores the urgent need for structured and sustainable housing solutions to support displaced populations during the recovery phases. By addressing key challenges such as cost-efficiency, cultural compatibility, and environmental impact, the study

aims to enhance the decision-making processes that govern temporary housing solutions. This scope highlights the complexities involved in balancing immediate relief needs with long-term sustainability in disaster-prone regions.

The experiences of post-disaster sheltering and temporary housing in similar developing countries, particularly Iran's neighbouring nations, reveal comparable challenges in making informed decisions about housing recovery models and selecting the most suitable transition strategies. Therefore, while the thesis is grounded in the Iranian context, the methodologies and insights it generates have broader applicability. Countries with similar challenges—high disaster vulnerability, resource constraints, and temporary housing issues—can potentially adopt the proposed framework. However, it should be clarified that this decision support system relies heavily on the expertise of local decision-makers, assisting them in considering a broader range of influential factors and applying their weights using a scientific approach. Moreover, the study's integration of sustainability principles and advanced decision-making tools could inform temporary housing strategies globally, facilitating improved disaster management outcomes in regions with comparable socio-economic and environmental conditions.

The particular focus of this research is on the temporary housing phase of disaster recovery, which serves as a critical bridge between emergency sheltering and permanent housing reconstruction. Temporary housing is not merely a stopgap solution; it has significant implications for the overall recovery trajectory of affected communities. By combining empirical insights from case studies in Iran with innovative technologies and decision-making methods, the research contributes to creating practical and adaptable housing solutions. This focus reflects the pressing need for efficient, sustainable, and culturally sensitive approaches to post-disaster housing worldwide.

1.6 Thesis outline

This research followed Massey University's thesis with publication guidelines.

This thesis consists of three main parts. The first part is preliminary studies, including the background studies and literature review. This part includes two chapters of the thesis and two papers. The second part is problem analysis, including case studies and explorative research. This part also consists of two chapters of the thesis and two research papers. The last part is dedicated to the research findings. Two chapters, including the decision support system development and the related paper, followed by the discussion and the conclusion from this part. The detailed correlation between the research objectives, thesis chapters, and scientific papers is shown through a flow chart in the research design subsection of chapter three.

This research followed Massey University's thesis with publication guidelines. According to these guidelines:

“In a Doctoral thesis with Publications, the doctoral student authors or co-authors multiple articles on their research during their doctoral programme. These articles are then collated and linked together to constitute the doctoral thesis. Each article will be structured in a way that is appropriate for the field and specific publication, often typically comprising an abstract, introduction with literature context, conceptual development or methods, results, analyses, discussion, and conclusions. This may lead to some repetition in a thesis of this nature, which is not in this context seen as a flaw. It is important to recognise that a thesis with publications is not composed exclusively of publications (see structure below). A doctoral thesis with publications must still demonstrate sufficient breadth and depth of knowledge in the discipline but do so using an appropriate number of discrete published articles as chapters.”

The description of each chapter in this thesis is as follows:

CHAPTER 1 begins with an introduction to natural disasters and forced displacement. The problem statement, research aim, and research objectives are explained, and the scope of the research is outlined in this chapter.

CHAPTER 2 is dedicated to the literature review. This chapter starts with post-disaster reconstruction characteristics and shelter problems, continues with a study of the latest technologies, and then explores the sustainability principles and their implications in reconstruction and temporary housing. This chapter includes two published papers exploring the construction technologies and sustainability of temporary houses, which are listed below:

- Shamloo, A., Wilkinson, S., Domingo, N. (2021). Reconstruction Technologies: A Study over the Effects of Construction Technologies on Post-Disaster Housing Recovery. 44th AUBEA conference; Deakin University, Victoria, Australia. (Published)
- Shamloo, A., Wilkinson, S., Elkhartoutly, M., Domingo, N. (2023). Sustainability of Post-disaster Temporary Houses: A Review of Principles and Assessment Methods. 13th Conference on Engineering, Project and Production Management; Massey University, Auckland, New Zealand. (Published)

CHAPTER 3 focuses on the research methodology. The research design is explained in this chapter and followed by the research philosophy and strategies. The data collection processes are explained in the last part of this chapter.

CHAPTER 4 studies the post-disaster recovery processes and utilised technologies for sheltering and temporary housing after seven earthquakes occurred during the past 20 years in Iran. This study focuses on the consequences of removing the temporary housing stage from the process, as well as the success stories and failures. This chapter includes the third published paper:

- Shamloo, A., Wilkinson, S., Elkharchoutly, M., Domingo, N. (2023). Post-disaster temporary housing in Iran: A qualitative study of processes and technologies. 46th AUBEA conference; Massey University, Auckland, New Zealand. (Published)

CHAPTER 5 includes a case study done following an earthquake in 2022. This qualitative assessment focuses on the performance of the foldable temporary housing units used in a village in southern Iran. This case study provides valuable insights into the latest temporary housing solutions used in Iran and explores the user's experience after two weeks of living in them. This chapter includes the fourth research paper:

- Shamloo, A., Wilkinson, S., Elkharchoutly, M., Domingo, N. (2025). Assessment of post-earthquake foldable temporary housing units in Iran: The case study of Sayeh-Khosh village. International journal of disaster resilience in the built environment. (Accepted)

CHAPTER 6 focuses on developing a multicriteria decision-support system for temporary housing. The temporary housing dilemma is explained, and an analytical hierarchy process is designed considering all required criteria for having a successful housing recovery process.

This chapter includes the fifth research paper:

Shamloo, A., Wilkinson, S., Elkharchoutly, M., Domingo, N. (2025). Developing a multi-criteria decision-aiding method for post-disaster temporary housing in Iran.

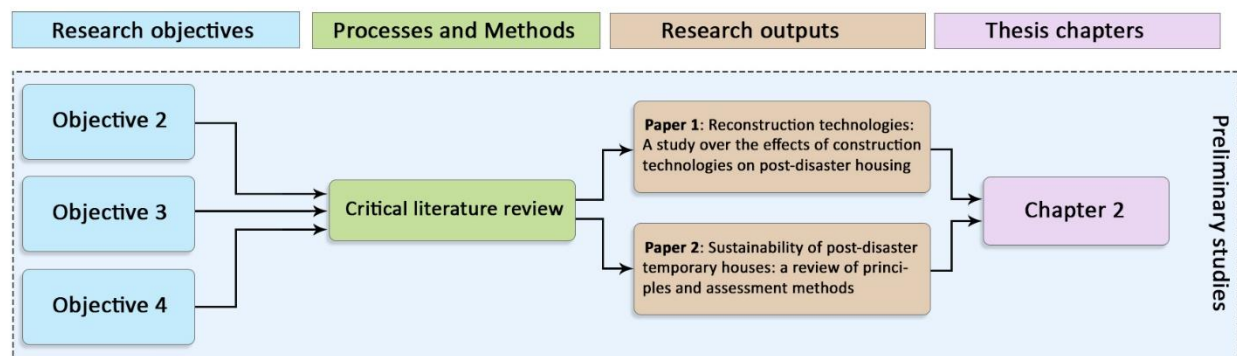
CHAPTER 7 is the discussion of the thesis. This chapter demonstrates an in-depth discussion of the details and facts revealed about post-disaster temporary housing in Iran, including challenges, and insights. This chapter also explains all the findings and lessons learned for improving the temporary housing processes in Iran.

CHAPTER 8 is the conclusion of the thesis, which briefly explains what has been achieved through this study. The conclusion is followed by some recommendations to decision-makers and policymakers. The research limitations and future research suggestions are the final parts of this chapter.

2 Chapter 2: Literature Review

List of publications constituting this chapter:

- Shamloo, A., Wilkinson, S., Domingo, N. (2021). Reconstruction Technologies: A Study over the Effects of Construction Technologies on Post-Disaster Housing Recovery. 44th AUBEA conference; Deakin University, Victoria, Australia. (Published)
- Shamloo, A., Wilkinson, S., ElkhARBoutly, M., Domingo, N. (2023). Sustainability of Post-disaster Temporary Houses: A Review of Principles and Assessment Methods. 13th Conference on Engineering, Project and Production Management; Massey University, Auckland, New Zealand. (Published)



STATEMENT OF CONTRIBUTION DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

We, the student and the student's main supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the student's contribution as indicated below in the Statement of Originality.

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In which chapter is the manuscript/published work? **Chapter 2**

Describe the contribution that the student and members of the supervisory team have made to the manuscript/published work:¹

Writing the original draft, review, and editing by Alireza Shamloo
Supervision by the supervisory team

Please select one of the following three options:



The manuscript/published work is published or in press

Please provide the full reference of the research output:

Shamloo, A., Wilkinson, S., Domingo, N. (2021). Reconstruction Technologies: A Study over the Effects of Construction Technologies on Post-Disaster Housing Recovery. 44th AUBEA conference; Deakin University, Victoria, Australia.



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Prologue:

This chapter establishes the theoretical and empirical foundation for the development of a decision-support system (DSS) dedicated to post-disaster temporary housing. As climate-related and anthropogenic disasters increasingly strain global humanitarian response and reconstruction capacities, the intersection of rapid shelter deployment, long-term sustainability, and strategic decision-making has emerged as a critical research frontier. This literature review synthesizes current knowledge on post-disaster housing recovery, beginning with an exploration of recovery stages and the socio-technical characteristics that underpin successful reconstruction. It then examines recent advancements in sheltering technologies, comparatively evaluating modular prefabricated, 3D-printed, and cast-in-place systems against key operational, logistical, and environmental criteria. The chapter further investigates the growing imperative of sustainability in reconstruction, reviewing established principles, assessment frameworks, and their practical application to temporary housing. Finally, it delves into the complexities of post-disaster decision-making, highlighting international and regional case studies that underscore the consequences of uncoordinated planning and identifying a critical gap in systematic tools for determining the necessity of temporary housing phases. By integrating these thematic strands, this chapter sets the conceptual groundwork for the methodological and developmental work that follows, ultimately guiding the design of a context-sensitive, evidence-based DSS for post-disaster temporary housing.

2.1 Post-disaster reconstruction

2.1.1 Shelter problem in the world, state-of-the-art

Post-disaster shelter provision remains one of the most critical and challenging components of humanitarian response. The immediate and long-term impacts of disasters, such as earthquakes, floods, hurricanes, and other natural hazards, necessitate rapid and effective shelter solutions. These challenges are particularly pronounced in developing countries, where limited resources, weak infrastructure, and heightened vulnerability complicate recovery efforts. The lack of adequate shelters can leave populations exposed to further risks, including diseases, exploitation, and adverse weather conditions (IFRC, 2022).

Developing countries often lack the financial resources to address the immediate and long-term needs of disaster-affected populations. While international aid plays a crucial role, it is frequently delayed or insufficient. For instance, in the aftermath of the 2010 Haiti earthquake, a significant funding gap hindered the reconstruction of homes, leaving thousands in makeshift shelters for years (Jha & Duyne, 2010). Furthermore, disasters often destroy critical infrastructure such as roads, bridges, and communication networks, making it difficult to deliver shelter materials and coordinate reconstruction efforts. The 2022 Pakistan floods, for example, submerged large areas, isolating communities and delaying relief efforts for weeks (Iqbal et al., 2024). Logistical constraints prolong the recovery phase and heighten the suffering of affected populations.

The disparity between the need for shelter and the available funding is one of the most pressing issues. Developing countries rely heavily on international aid, often allocated to immediate relief rather than long-term recovery. The World Bank's Disaster Recovery Framework Guide emphasises the critical need for establishing disaster recovery funds that can be mobilised swiftly and effectively. It highlights that in developing countries, international aid often focuses on

immediate relief rather than long-term recovery, underscoring the importance of dedicated recovery funds to bridge this gap (World Bank Group, 2020).

Disaster responses involve multiple stakeholders, including governments, NGOs, and international organisations. Poor coordination among these actors can lead to inefficiencies and duplication of efforts. For instance, during the Nepal earthquake of 2015, the lack of efficient community coordination hindered the process, as numerous affected regions depended on NGOs and local volunteers, resulting in scattered and uncoordinated recovery efforts. In this case, many survivors reported that aid was slow to arrive, and relief efforts were disorganised (Hall et al., 2017; Shrestha & Pathranarakul, 2018). Other problems associated with sheltering include the correct location finding and health risks. Overcrowding, inadequate sanitation, and exposure to harsh weather in temporary shelters increase the risk of diseases such as cholera and respiratory infections. In Mozambique, following Cyclone Idai in 2019, poor living conditions in shelters led to outbreaks of cholera, exacerbating the humanitarian crisis (Edson et al., 2020).

Addressing these challenges requires a multifaceted approach that combines resilience, community participation, and pre-disaster planning. By learning from past experiences and leveraging innovative strategies, it is possible to improve shelter responses and enhance the resilience of disaster-affected populations. Continued research and collaboration among governments, NGOs, and communities are essential to achieve sustainable and effective outcomes in the face of growing disaster risks.

2.2 Reconstruction technologies: a study of the effects of construction technologies on post-disaster housing recovery

Shelters are an emergency in the aftermath of a disaster; they provide the survivors with their most basic needs. After this stage, the recovery process should start quickly, which depends on quick decision-making over several related factors. Some of these critical factors include the place to rebuild houses (relocation issues, land tenure, accessibility, liveability, future hazards...), how to build (construction methods and technologies, materials, human resources, design...), and financial issues (Johnson & Lizarralde, 2012).

Quarantelli has defined four main stages for housing recovery, including emergency sheltering, temporary sheltering, temporary housing, and permanent housing, which are usually summarised into three stages. ‘Emergency sheltering’ is used during the height of the emergency and in the immediate aftermath; it may be as simple as plastic sheeting, staying at a neighbour’s house, or in a mass shelter, such as stadiums or urban shelters built for war or cyclone. In the ‘temporary housing’ stage, families are able to restore their daily activities, such as school, work, food preparation, and other social functions; however, in a temporary place, such as a small prefabricated house or a rented apartment ‘Permanent housing’ is the final stage in the housing recovery, when families have replaced their pre-disaster housing conditions with a long-term solution that is similar to past or, in a preventive mode, of better quality (Quarantelli, 1995).

Among these stages, permanent housing is a critical and time-consuming stage in the post-disaster recovery process, and according to the Federal Emergency Management Agency (FEMA), may take up to 5 years to get completed (Boyd et al., 2014).

Accelerating the permanent housing process can enhance the quality of recovery by reducing the consequences of living in inappropriate spaces. One of the most important reasons for providing a quick recovery is to prevent the unsafe rebuilding of the houses by the affected people or their self-resettlement in the disaster-prone areas, which will replicate the previous vulnerability. The desired quick recovery would be a complicated result of post-disaster management between interconnected influencing factors. Among these factors, which consist of social, economic, environmental and other determinatives, the role of construction systems and related technologies is also of high importance (Celentano et al., 2019).

During the last decades, a lot of rapid affordable housing concepts have been introduced and implemented worldwide, whether successful or not. Some of the main characteristics needed for these concepts to be more successful are discussed in the next part.

2.2.1 Post-disaster housing characteristics

In this section, some of the previous findings of post-disaster housing research and practices are reviewed briefly to extract the criteria for evaluation of related developing technologies.

There is an apparent emphasis on the importance of considering the survivors or affected people and communities as the main stakeholders of the reconstruction process. The success of a post-disaster reconstruction project mostly depends on being accepted and executed by the community, which can be achieved by considering several delicate factors (Charlesworth, 2014; Davis & Alexander, 2015).

2.2.1.1 Cost

Post-disaster housing resourcing and costs have always been a critical issues and depending on the location and country, can be a demanding parameter, especially where it meets annual inflation or the increase in overall construction cost as a consequence of the disaster (Silva, 2012).

Recent large-scale disasters have shown the importance of the availability of proper and adequate resources, such as building materials and construction practitioners, and their effects on the reconstruction process (Chang et al., 2012).

International organizations and governments in many countries can contribute limited budgets on post-disaster humanitarian housing projects, and as we see in practice, there is a clear gap' between the tendencies and solutions presented by the innovators and the possibilities at the societal level in an extensive emergency (Charlesworth, 2014).

2.2.1.2 Participation Capability

Housing reconstruction success is depended on involving the users in the design phases and construction process as well. In the other words, building systems and technologies more capable of users' participation in the construction process have more chance of leading to a successful housing recovery project. Research show that collaborative participation can solve complex, time consuming problems such as budget planning and also improve decision making process for future actions leading to a common benefit for all (Lizarralde et al., 2010).

Participatory processes in reconstruction, enable governments to share information about local hazards and vulnerabilities while gathering insights about residents' needs and priorities. This approach helps planning agencies develop new ideas and alternatives for recovery by incorporating diverse perspectives on recovery challenges. These new ideas and perspectives are crucial for

adapting to the rapidly changing recovery environment and enhancing the legitimacy of recovery plans (Hamideh, 2020).

Davidson et al. (2007) believe that participation in reconstruction projects has been shown to empower beneficiaries and community members by involving them in the political process and giving them a voice in decisions that shape their community. Although, there is no single "best" approach for user participation, as reconstruction processes are influenced by their socio-political and economic contexts, certain principles can guide strategic planning to create a balance between short-term project goals with long-term outcomes. The term "organizational design" is used to refer to these principles.

2.2.1.3 Construction Time

Permanent housing, as mentioned before, is a time-consuming process that can take up to five years to be completed. Reviving livelihoods, which is an important part of post-disaster recovery, is dependent on the housing reconstruction timeframe. Comparing 7 determining factors, Tas et al. (2010) indicates the time as the most determining/restricting problem in the design and construction of post-disaster permanent housing through the studies of an earthquake in Turkey (Figure 2.1).

Figure 2.1. Ranking of the influential factors in permanent housing.

Source: Case study of the Kocaeli earthquake in Turkey, 1999 (Tas et al., 2010)

There are important advantages resulting from shortening construction time, such as decreasing the extra expenses caused by inflation and changes in materials and workforce costs (Gunawardena et al., 2014).

2.2.1.4 Logistics

The success rate in logistic operations in a post-disaster situation has a significant influence on decreasing the negative social and economic impacts in humanitarian activities and on the quality of care as well. The logistics are also a significant part of every sheltering and housing process (Bastos et al., 2014).

In order to have a successful rebuild after disasters, the self-reliance of the community should be considered as an important factor. Utilising vernacular materials and facilities and local means of building houses, as well as noticing the local context features have always been emphasised within the literature (Johnston et al., 2022; Paton et al., 2015).

2.2.1.5 Design (Functional and Cultural Acceptance)

Cultural issues and the design acceptance of post-disaster housing projects have been under debate for a long time. The inappropriateness of design is rooted in various factors, such as misunderstanding of local needs by executive agencies, which may lead to beneficiaries' refusal to inhabit the new houses, make changes to them or sell their components. Inappropriateness appears in the size and form of houses, spatial design, interior design of the houses and the surroundings, material usage and infrastructural plans. In most cases, the importance of consultation with beneficiaries is recognised by the agencies, but it is not sufficient, and so, reconstruction project failure is likely to continue despite spending huge amounts in budget and time (Ahmed, 2011).

2.2.1.6 Liveability

A study on post-disaster done by the Humanitarian Practice Network defined housing as “the process of providing permanent dwellings and the related physical, social and administrative infrastructures”. Houses are created as the result of this process, while their design and materials, as well as their function, vary among different cultures. The definition emphasises liveability and the local context as important parts of the housing process, expressing a human-centred approach (Barakat, 2003). In other words, as Charlesworth and Ahmed (2015) emphasise, the most effectiveness of the housing recovery process is not achieved unless it includes the community requirements and makes appropriate connections to infrastructures and services, which leads to the creation of true livelihoods.

2.2.1.7 Resilience

Post-disaster housing recovery shouldn't be summarised in replacing the destroyed house. Instead, as evident in the literature, it should lead to a safer and more over, a more resilient house which doesn't simply recreate the vulnerable condition which existed before the disaster and creates an opportunity to build back better (Aquino et al., 2019).

In the case of the success of Building Back Better, which leads to a more resilient community, a sense of security is created, which stems from the fact that the buildings and community are safer than before. In such a community, a new normal stage appears that includes higher readiness for confronting future disasters and the buildings more capable of coping with future threats. Future-proofed communities in this scope are the result of considering the recovery process as an opportunity for building back better (Mannakkara et al., 2018).

2.2.1.8 Environmental Effects

Climate change is increasing natural disaster rates and the built environment, considering both construction industries and buildings' energy consumption are responsible for the biggest part of CO2 emissions, which is the main reason for climate change (IEA, 2022). As mentioned before, post-disaster housing is an opportunity to build back better, so, it can be an opportunity to reduce the environmental footprints of the buildings, from using sustainable materials to reducing energy consumption and carbon footprint.

2.2.2 Recent structural systems advancements

2.2.2.1 Modular Prefabricated Structures

Modular and prefabricated structures are useful concepts broadly used in construction. The extensive substantial characteristics of modular structures, as indicated below, allow for rapid construction as well as simple on-site construction, making it friendlier to the end user. Some characteristics of modular structures are listed here:

Modular structures can include all components of a building such as stairs, lift shafts, rooms, corridors, services and façades. The mass production of these modules has valuable advantages of higher quality and lower price. The shape and size of modules can be different and just limited to transportation facilities. Due to incorporating the façade and interior components into modules, the on-site work is minimized. The modules have the ability to be detached and reused in other places. Modular structures can reduce the construction time by 50 percent compared to on-site construction techniques and this makes the building habitable sooner (Lawson et al., 2012).

Recently, Vectorminima, a new Canadian company, has developed a highly optimised volumetric structural solution that minimizes material, manpower and setup time, both in the fabrication plant

and on the job site. The new structural system with commercial name of Metaloq is a Cold Formed Steel (CFS) module framing system (Figure 2.2).

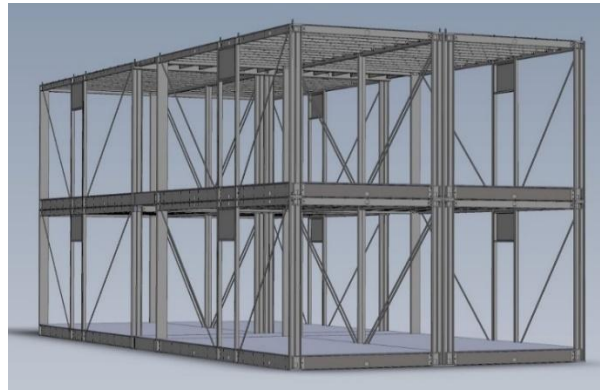


Figure 2.2. Metaloq modular framing system by Vectorminima.

Source: (Davies, 2020)

The remarkable features of this modular framing system include innovative connections resulting in fast and simple installation, high precision, minor shipping space, low weight (60-80 kg/m²), building in height (up to 10 stories), integrating mechanical, electrical, and plumbing (MEP) connections into the units and using recycled steel (Davies, 2020).

In another innovative modular structure project, a recent research by Casagrande et al. (2021) at National Research Council of Italy has developed a new timber construction system called “Hybrid Timber Frame” (HTF). The system combines cross laminated timber (CLT) and an innovative connection system which has been specifically developed to increase the speed of assembling and dismantling of walls. This connection system is preinstalled at the four corners of the panel and, during the assembling phases, it simply requires to be bolted to the foundations without additional screws or nails. The innovative anchoring system, enables each wall module to be removed and re-used in a different location with few on-site operations. Furthermore, the traditional permanent

foundations (typically concrete foundations) are replaced with a prefabricated system composed of a grid of steel beams placed on concrete supports.

Figure 2.3. Hybrid Timber Frame (HTF) modular structure

Source: Casagrande et al. (2021)

By prefabricating and mass production of modular structures, a large number of houses can be built and installed in a relatively short time, and this can decrease the time needed for reviving the livelihood in affected communities.

2.2.2.2 3D Printed Structures

The first 3D printer was invented in 1984, and since then, 3D printing has become one of the fastest-growing technologies in many industries. Since 2014, real revolution in construction industry has started and by printing the first house, a new chapter in construction technologies started (Hager et al., 2016).

Early construction 3D printing development and research have been under way since 1995. The contour crafting technique patented by Behrokh Khoshnevis in 1995, was an innovative extrusion and shaping method, as an alternative to the emerging polymer and metal 3D printing techniques.

Khoshnevis realized that this method could exceed the current techniques of that time which were limited to fabrication of part dimensions that were usually less than one meter in each dimension. Around 2000, Khoshnevis's team at USC Vertibi began to work on building scale 3D printing of cementitious and ceramic pastes, encompassing and exploring automated integration of modular reinforcement, built-in plumbing and electrical services, within one continuous build process. The elimination of formworks was one of the major benefits resulted by the development of 3D printers (Sanjayan & Nematollahi, 2019).

In recent years, 3D printing technology have been tested for construction of buildings, bridges and architectural forms. In 2018 the Italian company Wasp printed a small house using raw soil, straw, lime and some natural waste materials from rice without using cement. The importance of the project was in using large proportion of materials from the site and almost zero environmental impacts. The company is working on another sustainable habitat project called Tecla since 2019 which is the first house to be entirely 3D printed using locally sourced clay (Moretti, 2023)

Figure 2.4. TECLA sustainable habitat project by WASP

Source: (Moretti, 2023)

2.2.2.3 *Cast-in-Place Concrete Structures*

There are various methods for building on-site bearing concrete walls which provide both structural and dividing walls (in terms of separation and space creation) at the same time. These methods include shotcrete and cast in place technics like traditional formwork technics, ICF technology, Moladi formworks technology and so on.

Cast-in-place concrete can be economically feasible. Much of the cost factor is related to the depth of the structure. Shotcrete is a good option when wall sections range in thickness from 6 to 12 in. Both of these options are usually cost-effective. Thicker sections of concrete walls require traditional concrete forming to maintain the cost-effectiveness (Woodson, 2012). Cast-in-place concrete requires formwork to define its shape during the curing process. The most common materials used for formwork include plywood and milled lumber, metal formworks, and plastic formworks (Kubba, 2010). Moladi formworks are reusable (up to 50 times) and they can be recycled after that. In this system, lightweight panels are configured into a mould which forms a house of any size and the concrete is placed at once. The thickness of smooth walls created in this method are 10 or 15 centimetres (Matamanda et al., 2022).



Figure 2.5. Moladi formwork, a cast-in-place structural system

Source: Moladi (2018)

2.2.3 Comparison and discussion

In this section, three structural systems introduced in the previous section are compared based on their major features, and the results are shown in Table 1. Some features, such as liveability and resilience, are defined in connection with the context, location and infrastructures, so the structures alone cannot be compared based on them. The other features include main materials needed, manpower, construction Time, logistic features, design capabilities and environmental considerations.

Metalog modular frames are capable of reducing costs by 25 per cent due to time-saving and using less steel and ironwork compared to conventional steel structures. 3D printers also have the potential to make remarkable savings by autonomous construction, this can reduce the costs to near zero when using local soil as the main part of mortar. Moladi plastic formworks are capable of reducing the costs by 30% in compare with traditional brick and mortar methods (Davies, 2020; Matamanda et al., 2022; Moretti, 2023).

In terms of construction time and manpower, Each Metalog module is assembled in 2 hours by skilled workers and connected to the other modules in 18 minutes, but this includes only the structure and not the walls. A Moladi concrete structure takes 2 days to be completed by simple laborers and the walls are ready to be painted after that. Gaia 3d printed house was built in 10 days and the more recent Tecla project was printed in 200 hours. However there have been better records in the 3D printing concrete industry, for example, the BOD 2 printer by COBOD Company has the potential to print 100 cm per second which is equivalent to printing 10 tons of concrete per hour (Davies, 2020; Matamanda et al., 2022; Moretti, 2023).

In order to build a 45 m² space in 2 days using Moladi formworks, 6 to 10 people are needed. 3D printers need few operators, and the Metaloq modular frames has decreased the need for ironworkers by using an innovative connection at structure joints, so that they are installed quickly using simple tools and few workers. 3D printers almost eliminate the need for participation of survivors and local people, except in concepts like the Tecla project which relies on local materials that can be delivered and sorted by people. 3D printers are capable of building various forms and this can meet the users' needs in future (Davies, 2020; Matamanda et al., 2022; Moretti, 2023).

Although steel industry has a significant carbon footprint, Metaloq modular frames minimize the steel use and they have been made by recycled steel, so they are affecting the environment less than other steel frames. Cast in place concrete structures and most 3D printed structures are based on cement which is also one of the main sources of carbon emissions, but, in concepts like Tecla, the carbon foot print is near zero thanks to the sustainable mortar made from soil and bio-materials deriving from rice cultivation waste, this problem is tackled successfully.

In terms of logistics and transportation, all 3 technologies have remarkable advantages. Despite conventional modular houses, Metaloq structural elements are transported in pieces, which allows a lot of them to be fitted in a container. In 3D printing technologies, by delivering the printer facilities and using local materials the need for transportation facilities is minimized and in Moladi system, the lightweight formworks can be delivered easily and reused several times.

One of significant factors for evaluating structures while considering building back better instructions in a global scale, is their environmental effects and sustainability. Being carbon neutral and using fully sustainable materials the Tecla project is successful in this scope, but it seems to be designed as a basic habitat for poor countries which form a large part of world population and it doesn't fit the needs of urban people in developed countries.

Table 2.1. Comparing the Housing capability of 3 different Structural systems

Features/Systems	Metalog modular framing (Modular Prefabricated Structure)	WASP 3D, TECLA project (3D Printed Structure)	Moladi formworks (Cast in place concrete)
Main materials	Steel profiles and wood/ drywall	Mortar (based on soil)	Concrete and reinforcement
Labourers	4 skilled workers	2 skilled workers/ operators	6-10 simple workers
Construction Time	2 hours (one module of structure only)	10 days (Walls)	2 days (Walls)
Logistic features	The most compact form of Modular structures	Reusable printer facilities and Local materials	Light and reusable Plastic formworks
Design Capabilities	Depending to the module design	Free forms	Depending to the formwork shapes
Environmental Considerations	Reducing steel amount Using recycled steel	Sustainable local materials	Reusing and recycling plastic formwork
Distinct feature	Multi-story construction (up to 10)	Using local soil as the main material	Simple technology

Data in the table is approximate and retrieved from the producers' websites and references (Davies, 2020; Moladi, 2018; Moretti, 2023).

The main advantages of modular structures include prefabrication, quick installation and land saving resulting from multi-story construction. Modular structures also benefit from offsite construction in a controlled environment that has advantages including higher quality, higher efficiency, higher safety and less wastage (Kolo et al., 2014). In 3D printed structures autonomous construction, low costs and the variety of forms are notable advantages (Sanjayan & Nematollahi, 2019). and in cast in cast-in-place structures, the simplicity of the process and materials, the fast construction and the high strength of the structure are remarkable points. Cast-in-place concrete technologies like Moladi formworks are simple, applicable solutions for developing countries with less cost and higher strength compared to traditional walls. They can give an acceptable result in a short time using simple labourers, which has made them a handy method. However, they may give their place to autonomous construction technologies in future.

2.2.4 Conclusion

According to the literature, several factors are influential in the success of post-disaster housing projects. From decision making on where and how to rebuild, to financial management and social issues. In this complicated context, structural advancements can help to reduce the construction time and construction costs as well or to improve the other features described as the characteristics of acceptable and successful post-disaster housing. Three structural systems with high capabilities in post-disaster construction are compared in this paper based on the main features required for a successful housing recovery.

The research shows that the comparison between structures is complicated, and this is rooted in the different characteristics of each structural system, which makes it suitable for different circumstances. Moreover, the 3D printed structures are still at the basic levels of their progress, and some of the major built samples are, in fact, prototypes and will be more efficient after further developments.

The findings show that each structural technology has unique features making it suitable to meet some parts of post-disaster housing needs, from time and cost savings to land use reduction and environmental considerations. Comprehensive knowledge of these technologies may help governments, people and organisations practising post-disaster construction to make appropriate decisions in accordance with peoples' needs. In this approach, technologies are looked at as means of creating people-centred solutions for reconstruction.

2.3 Sustainability of post-disaster temporary houses: a review of principles and assessment methods

2.3.1 Introduction

The growing population of the world, global climate change, and the mounting number of climate-related disasters have increased the number of displaced people and the need for post-disaster housing (Perrucci et al., 2016). According to the latest report by the United Nations High Commissioner for Refugees (UNHCR), the overall number of people forcibly displaced worldwide has grown to 108.4 million in 2022, which is more than twice the number of forcibly displaced people a decade ago (UNHCR, 2022). As the “Global Report on Internal Displacement (GRID) 2023” report by the Internal Displacement Monitoring Centre (IDMC) shows, over 32 million displacements in 2022 have been related to disasters, which indicates the extent of the need for reconstruction of houses and settlements around the world (IDMC, 2023). According to the building back better concept, to prevent the recreation of the vulnerabilities in the built environment, the resilience and sustainability factors should be considered carefully in reconstruction projects (Mannakkara et al., 2018).

Global challenges like climate change have shown that sustainable development is an inevitable roadmap for saving future generations. It has been proved that embracing sustainable development principles in the construction sector is crucial to safeguarding the environment, improving quality of life, promoting economic growth, and addressing climate change challenges. It aligns with the broader goal of creating a balanced and resilient society that meets the needs of the present without compromising the ability of future generations to meet their own needs. Sustainable reconstruction is becoming an essential need, and temporary housing needs to meet sustainability standards as a part of the reconstruction process. Despite this, temporary housing solutions such as prefabricated

units are often criticized for weak sustainability performance (Atmaca, 2017; Hosseini et al., 2021).

2.3.2 Research method

The research method employed for this review paper is a critical and comprehensive approach to gathering and synthesizing existing scholarly works related to sustainability in reconstruction and temporary houses. This method involves a thorough search of reputable academic databases to identify relevant articles, books, and other sources. After the initial selection, a secondary screening process is conducted to ensure the inclusion of high-quality and pertinent literature. To classify the state of knowledge on the subject, the findings are classified into three subsections: sustainable housing, sustainable reconstruction, and sustainable temporary housing. The main goal of this study is to review sustainability principles and assessment tools in the post-disaster context. For this purpose, the paper starts with general sustainable housing attributes and assessment systems and then studies the post-disaster construction characteristics and related sustainability guidelines and assessment tools.

2.3.3 Post-disaster construction

Post-disaster housing processes start with emergency sheltering and finish after the permanent housing stage. Quarantelli (1995) defines four main stages for housing recovery: emergency sheltering, temporary sheltering, temporary housing, and permanent housing. The first stage includes finding a safe place to stay for the first nights. Other references, for instance, Davis and Alexander (2015), summarized post-disaster housing into a three-stage model of temporary sheltering, temporary or transitional housing, and permanent housing. Post-disaster temporary housing strategy is not necessarily the best solution after a disaster. Temporary housing units (ready-made units) have several problems, including high expenditures that may lead to delays in

permanent housing, being undesirable or unacceptable in meeting displaced people's needs, limiting their participation capabilities in the reconstruction process, and also adverse effects on the environment. An alternative solution is a two-stage recovery in which the transitional housing can be omitted. This model of housing recovery is based on extending the emergency shelter usage or using alternative available settlement options and accelerating the permanent housing process. It requires pre-plans for reconstruction and the use of rapid construction technologies for permanent housing (Davis & Alexander, 2015).

However, temporary housing is considered to have a critical role in the recovery process. Providing a temporary “home” as a safe place for survivors to live in (until the permanent houses are built) is among the first essential steps in the recovery process. This is rooted in the fact that losing a house is more than just a physical loss and affects all aspects of the survivors’ lives, from privacy and mental health to security and safety against illnesses and pollution (Bashawri et al., 2014). The experiences of previous disasters have shown that extensive usage of temporary housing facilities is inevitable in some cases, which is mostly a function of the disaster scale, resourcing shortages, and the weather conditions (Fallahi & Arabpour, 2007; Johnson et al., 2006; Lizarralde et al., 2010; Perrucci & Baroud, 2020).

2.3.3.1 Temporary housing

The temporary housing phase begins after the emergency and temporary sheltering stage and usually lasts for six months to three years (Perrucci & Baroud, 2020). Temporary housing has two major options. The first option is using existing facilities, such as available rental accommodations, collective living spaces, re-purposed public buildings, and so on, and the second option is providing temporary houses by building them in place, assembling kit structures, or delivering prefabricated units (Lizarralde et al., 2010).

According to Hosseini et al. (2019a), an appropriate strategy in selecting a suitable temporary housing type is derived from the capability of that system to match the local circumstances, and the lack of coordination between the selected temporary housing system's specifications and the local stakeholders' needs will result in the failure of the recovery project. Temporary houses have a wide variety and are built using a wide range of structural systems and materials. Some of the most commonly used temporary housing solutions are listed in Table 1.

Table 2.2. Temporary housing structures and materials.

Temporary housing structural systems	Main materials
Sandwich panel units	EPS, steel/aluminum sheet, plywood/ fiberboard/ PVC wall covering
Shipping containers	Corrugated steel sheets and profiles
Bamboo/reed structures	Bamboo, reeds, straw, or metal or plastic sheet roofing
Paper tube structures	Paper tube, fiberboard floor, metal or plastic sheet roofing
Reinforced masonry structures	Stone, brick, concrete, steel rebar, corrugated metal roofs
Steel framed structures	Steel profile, different wall options (brick/ concrete, clay, or AAC blocks)
Timber-framed / Wooden structures	Sawn timber, wooden walls, corrugated sheet or straw roofing
Concrete structures (cast-in-place, 3D panel)	Concrete (cement, water, aggregates), steel mesh/ rebar, EPS
Earthen structures	Rammed earth, Superadobe, compressed earth blocks
Hybrid and composite structures	Different options (wood/ plastic/ metal/ fiberglass and ...)
3D printed structures / 3D printed components	Concrete, soil, corrugated sheet roofing
Modular structures / Kit structures	Different options (wood/ plastic/ metal/ fiberglass and ...)
Tensile structures / Long-term tents	Polyester, fabric, ETFE, and ...

Retrieved from sources: (Casagrande et al., 2021; Celentano et al., 2016; Das & Mukhopadhyay, 2018; Davis & Alexander, 2015; Faragallah, 2021; Zea Escamilla & Habert, 2015; Zhang et al., 2014)

2.3.4 Sustainability

Since 1990, numerous sustainability guidelines and principles have been proposed worldwide (Shrivastava & Berger, 2010). According to one of the first definitions by the World Commission on Environment and Development report in 1987, “Sustainable development is a development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (Brundtland, 1987). UNESCO considers four dimensions for sustainable development: society, environment, culture, and economy. The United Nations Department of Economic and Social Affairs, in the “Transforming our World: 2030 Agenda for Sustainable Development” (UN, 2015), has defined 17 sustainable development goals (SDGs). In this guideline, the sustainability of human settlements is the 11th goal, and it is emphasized that sustainable housing and urban development are among the essential SDGs crucial to the quality of life of people. Sustainable housing is considered one of the most important individual elements of sustainable development (Brian Edwards & D. Turrent, 2000).

Among the 17 SDGs, sustainable construction firstly contributes to SDG 11, which aims to make cities and human settlements inclusive, safe, resilient, and sustainable. Sustainable construction practices reduce urban sprawl, promote energy efficiency, and enhance infrastructure, thereby fostering more livable and eco-friendly cities. Furthermore, sustainable construction aligns with SDG 9 by developing innovation and building resilient infrastructure, essential for economic growth and industrial development. By prioritizing sustainable materials, efficient energy use, and waste reduction, it directly supports SDG 12, which targets responsible consumption and production patterns. Lastly, sustainable construction also advances SDG 13 on climate action, as it reduces carbon emissions and helps mitigate the impacts of climate change. In essence, sustainable construction emerges as a linchpin in the global pursuit of the SDGs, providing the

foundation for a more equitable, prosperous, and sustainable future for all (Opoku et al., 2022; Scrucca et al., 2023).

Sustainable reconstruction has gained more notice in recent years because of the increasing number of climate-related disasters and awareness of the unsustainable development consequences. According to Goubran (2019), the building industry is the most significant sector in terms of emissions, and the construction and real estate sectors can contribute to achieving 44% of all targets in all 17 SDGs. In this regard, sustainable reconstruction as an opportunity to build back better and a significant part of the construction industry plays an important role in achieving the SDGs.

2.3.4.1 Sustainable housing

Sustainable housing is not a new concept; numerous studies and practices have been done in this field in the last three decades, and there are clear guidelines, principles, and assessment systems for sustainable development and sustainable housing (Brian Edwards & D. Turrent, 2000; Ming Yip & Mohamad, 2017). The built environment and construction industry account for a large portion of the global energy consumption and greenhouse gasses (GHGs) emissions. Buildings are responsible for half of the global energy use and over 30% of CO₂ emissions (IPCC, 2015; Lazar & Chithra, 2020; Olu-Ajayi et al., 2022). In this sector, considering the overgrowing population of the world, the housing industry and residential buildings play an important role, as they form the largest part of the built environment. Housing has the potential to contribute to sustainability by being built of local materials and with less carbon footprint (Murtagh et al., 2020; Winston & Pareja-Eastaway, 2008).

Sustainable housing, as a cornerstone of sustainable construction, focuses on energy-efficient design, renewable energy integration, and environmentally friendly building materials. By

reducing energy consumption and carbon emissions, sustainable housing plays a vital role in mitigating climate change. Sustainable housing not only minimizes the carbon footprint of individual dwellings but also sets a precedent for sustainable urban development. Moreover, sustainable housing fosters healthier and more comfortable living environments, promoting well-being while addressing social and economic aspects of sustainability. In essence, sustainable housing serves as a critical component of the broader effort to curb climate change and promote a more resilient and environmentally conscious future (Geropanta et al., 2021; Jacobs, 2023).

Robichaud and Anantatmula (2010) believe that the main goals of sustainable housing can be summarized as minimizing the environmental footprint, improving the health of occupants, returning the investments to local communities, meeting sociocultural requirements, and enhancing the lifecycle considerations.

Having examined the literature, sustainable housing attributes can be sorted based on three pillars: environmental, economic, and sociocultural indexes. Figure 2.6 shows the most common attributes and indicators of sustainable housing retrieved from the literature. Greenhouse gas (GHGs) emissions and carbon footprint and their impacts on climate change have gained more attention among the extensive characteristics and indicators of sustainable housing, and most of the sustainability attributes of Table 1 have direct or indirect impacts on GHG emissions.

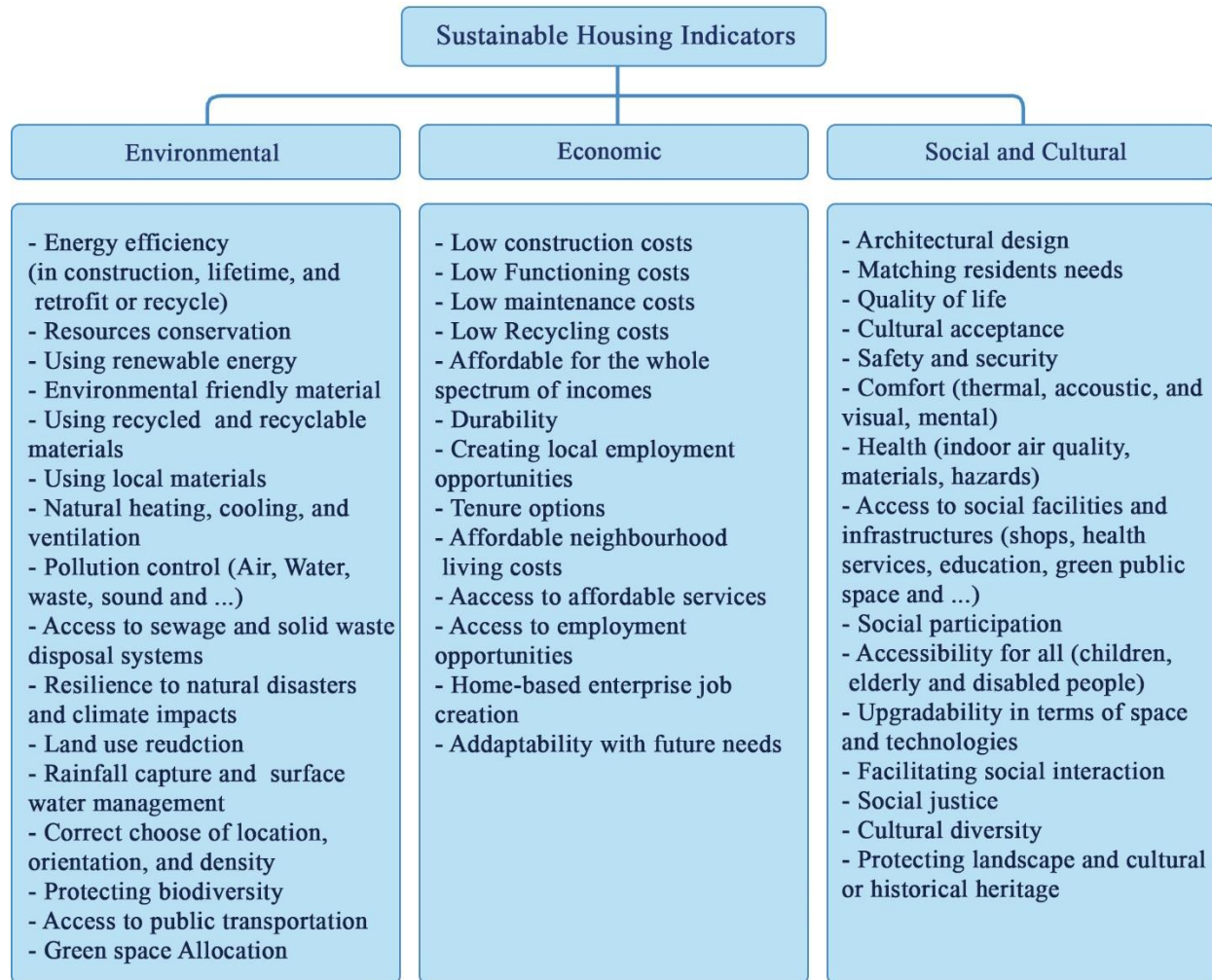


Figure 2.6. List of sustainable housing factors retrieved from the literature

Source: (B. Edwards & D. Turrent, 2000; Ming Yip & Mohamad, 2017; Robichaud & Anantatmula, 2010; Tayefi Nasrabadi & Hataminejad, 2019)

2.3.4.2 Sustainable reconstruction

Disasters can easily disrupt the usual functions of a society (Frimpong, 2011). From another point of view, disasters are also valuable opportunities for addressing the deficiencies and vulnerabilities of the built environment and, moreover, implementing sustainability and resilience principles to create a more resistant and greener community (Tomkinson, 2013). Sustainable housing

(temporary and permanent) in a post-disaster context has a distinctive difference from sustainable housing in general terms; it is mixed with necessity and urgency. The need for immediate decisions and restoring services while considering the long-term requirements of sustainable development is the main challenge in sustainable reconstruction, which can mean housing recovery projects have conflicting objectives (Johnson et al., 2006; MacAskill & Guthrie, 2014).

Sustainability principles encompass a holistic approach that considers environmental, social, and economic dimensions, advocating for efficient resource utilization, reduced carbon footprint, equitable access to resources, and community engagement. By prioritizing sustainable infrastructure, renewable energy sources, disaster-resistant designs, and inclusive decision-making processes, post-disaster reconstruction can mitigate future risks, foster adaptive capacities, and promote equitable development trajectories. The imperative for sustainability in post-disaster reconstruction resonates with global commitments to sustainable development and climate action, underscoring the pivotal role it plays in shaping the trajectories of disaster-affected regions and fostering a more resilient and harmonious coexistence between human societies and the natural world (Dube, 2020).

Meeting post-disaster housing requirements through sustainable and resilient reconstruction methods should be a goal for strategic decision-makers and people. According to research by Mannakkara et al. (2018) and Charlesworth and Ahmed (2015), the experiences of the practitioners in the field show that sustainable reconstruction success depends on the appropriate implementation of several factors, including integration of housing with infrastructures, supporting livelihoods and local economy, sustained engagement of organizations, ensuring multi-stakeholders engagement, using local built environment professionals help, and having an owner-driven approach.

2.3.4.3 *Temporary housing sustainability*

Although sustainability is a key factor in urban development and housing, it is often neglected in post-disaster sheltering or temporary housing (Pomponi et al., 2019). Temporary housing solutions are normally considered to be used for several months or a few years, but experiences across the world show that, in practice, they may be in use for several years (Zhang et al., 2014).

Research by (Bashawri et al., 2014; Hosseini et al., 2019b; Johnson et al., 2006; Zea Escamilla & Habert, 2015) show that the most important factors for achieving successful and sustainable temporary housing are:

- Meeting the displaced people's needs and cultural properties
- Low costs and availability
- Meeting climatic and geographic specifications
- Short building/ provision/ delivery time and ease of construction or transportation
- Safety and Security
- Privacy and comfort
- Suitable location and communication
- Supporting livelihoods
- The ability to be reused or recycled
- Minimizing environmental impacts

With an increasingly developing climate crisis, providing sustainable temporary houses will remain one of the most important and influential objectives. Changing material types and a need to provide reduced resource usage means that new mechanisms for sustainable temporary houses

are required. The most frequently observed problems with temporary housing projects within the literature include incompatibility with the survivors' needs, high expenditure, wrong location, and environmental impacts (El-Anwar, Asce, et al., 2009; Fayazi & Lizarralde, 2013). These incompatibilities have led to the rejection of the survivors to use temporary houses or using them with dissatisfaction in several cases. For instance, after the 2003 earthquake in Bam (Iran), parts of the temporary facilities remained useless due to their inappropriate location; or after the 2004 tsunami of Aceh (Indonesia), the changes in the recovery approach led to late delivery and poor quality of temporary housing (Da Silva et al., 2010; Davis & Alexander, 2015; Fayazi, 2012).

Figure 2.7. Temporary housing solutions designed by Shigeru Ban

Source: Boardman (2017)

According to the mentioned sustainability principles, to have a sustainable shelter, not only should the materials be from reusable, recyclable, or biodegradable sources, but also the reasonable costs, compatibility with climate and social requirements, and availability are some of the most important factors. Figure 2.7 shows two shelter concepts designed by the humanitarian architect, Shigeru Ban. One of them is mostly based on reeds and plants, and the other one is built using paper tubes.

2.3.5 Assessment systems and methods

Building sustainability assessment systems are designed and used in order to find out to what extent a building meets the requirements of sustainability. According to Beardsley et al. (2017), the main purposes of assessments include: improving the designing and building process of new buildings, evaluating the sustainability of existing buildings, Verifying compliance with national and international regulations, and raising general awareness and educational purposes.

The assessments are based on weighting and aggregating sustainability indices and their components (Gan et al., 2017). The literature shows that in the past 30 years, the number and complexity of environmental assessment tools designed for buildings have increased, and now, there are over 150 tools for assessing and benchmarking buildings (Beardsley et al., 2017). Among these assessment tools, some of the internationally recognized systems are LEED, BREEAM, CASBEE, SBTool, SBAT, HQE, GBND, GBI, and so on (Beardsley et al., 2017; Charoenkit & Kumar, 2014). Most of these assessment systems have a set of tools developed for various categories, such as sustainability assessment of houses, neighbourhoods, urban infrastructures, and so on. Despite the availability of a wide variety of assessment tools, researchers and organizations are constantly developing new sustainability assessment tools, which are mostly customized tools for special locations and types of buildings.

A recent study by Lazar and Chithra (2020) shows that the majority of building sustainability assessment tools are designed based on environmental sustainability, and this is because of the important role of environmental considerations in sustainable development.

2.3.5.1 Reconstruction sustainability assessment

Sustainability assessments of post-disaster or post-crisis reconstruction programs are done to show how much the processes are compatible with long-term goals of sustainability. This can help planners and decision-makers improve future reconstruction efforts and decrease the harmful consequences of inappropriate environmental choices (Zea Escamilla & Habert, 2015).

There are tools especially developed for the assessment of post-disaster reconstruction processes. One of these tools is QSAND (Quantifying Sustainability in the Aftermath of Natural Disasters). QSAND is an open-source shelter and settlement sustainability and resilience self-assessment tool. It has been developed on behalf of The International Federation of Red Cross and Red Crescent Societies (IFRC) and follows the standards developed by the BREEAM assessment system. It covers eight categories of sustainability factors that are:

- *Shelter and community*
- *Settlement*
- *Material and waste*
- *Energy*
- *Water and sanitation*
- *Natural environment*
- *Communications*
- *Cross-cutting (QSAND, 2022)*

The other tools include PASSA (Participatory Approach for Safe Shelter Awareness) and T3B (Talk to the Buildings), which is more based on achieving sustainability qualities through design

and architectural patterns. In this method, ten essential patterns of creating a “Home” are the basis for the sustainability assessment of post-disaster shelters and houses (Potangaroa, 2015).

2.3.5.2 Sustainability assessment of temporary houses

Temporary housing sustainability assessment is a part of the whole post-disaster recovery assessment. Regarding the long period of survivors' settlement in post-disaster temporary houses (which lasts for several months to a few years), their sustainability as a part of residential buildings needs to be assessed. This can contribute to minimizing the negative environmental impacts of human settlements (Atmaca, 2017).

Temporary housing sustainability assessment includes the assessment of the whole process and the life-cycle assessment of temporary houses/ units. Post-disaster temporary housing as a process, needs several decision-making; including the location of temporary houses, type and technology, building method, materials, and so on (Kapucu & Garayev, 2011). Hosseini et al. (2021) believe that the appropriate decision regarding the selection of an optimal temporary housing strategy is a result of considering the natural hazard characteristics, the local characteristics, and the temporary house characteristics, and experts from different disciplines should be involved in the temporary housing processes.

Examining the literature shows that sustainability assessment and decision-making over temporary houses and shelters has a shorter history compared to permanent houses. One of the first researches was done by El-Anwar et al. (2008), in which they developed a model by quantifying the qualitative specification of temporary houses and their impacts on the users. During the last decade, several other pieces of research have been done on temporary housing sustainability assessments. S. M. A. Hosseini et al. (2016) developed a selection model based on sustainability

indicators of temporary houses, including provision cost, maintenance cost, health, well-being, resource consumption, pollution, solid waste, and reusability.

Reviewing the literature reveals that because of the limited number of tools in reconstruction sustainability assessment, and especially in temporary housing assessment, researchers have tried to develop new methods and tools for the assessment of temporary housing sustainability. The most used method for developing a sustainability assessment is Multi-Criteria Decision Making (MCDM), which is a technique that combines each parameter's performance over numerous qualitative and/or quantitative criteria (sometimes contradicting each other) and results in a solution that needs a consensus. In this method, each assessment parameter is evaluated by considering its weight and impact (Lazar & Chithra, 2020).

2.3.6 Discussion and conclusion

Sustainability assessment in post-disaster construction plays a vital role in ensuring that rebuilding efforts not only restore communities but also contribute to long-term environmental and societal resilience. This process involves evaluating the environmental impact, resource efficiency, and social considerations of construction projects in the aftermath of natural or man-made disasters. By prioritizing sustainable building materials, energy-efficient designs, and community engagement, these assessments help minimize the ecological footprint, enhance disaster resilience, and promote the well-being of affected populations.

In this study, the main characteristics of sustainable housing and sustainable reconstruction have been collected and classified. Post-disaster housing processes and post-disaster temporary housing characteristics are explained. Finally, sustainability assessment methods in general and post-disaster fields are reviewed. According to the literature, despite the difficulties of considering the long-term requirements of sustainable construction in the emergency circumstances of post-

disaster recovery, moving toward sustainable reconstruction (temporary and permanent) is inevitable. The reason is climate change and the increasing number of natural disasters. Sustainable housing reconstruction should prevent future vulnerabilities and contribute to the reduction of climate change effects.

The findings of this study show that despite the numerous sustainability assessment systems in the world and in the built environment sector, there are limited resources and principles for the sustainability assessment of temporary houses, and one of the most used techniques is MCDM.

Although temporary housing sustainability assessment tools may have limitations and deficiencies in results, they can support post-disaster decision-makers in choosing the most appropriate solutions. Future research needs to provide a method for optimizing and advancing the sustainable features of temporary houses. Also, further research needs to be done on whether sustainability assessments of the most used temporary housing solutions in each country/region against the prevalent disasters actually reduce climate change impacts or not.

2.4 A successful recovery characteristics

The literature on post-disaster reconstruction identifies several critical characteristics for ensuring successful recovery that can be summarised as the following:

1. First, focusing on resilience and sustainability is paramount, emphasising the principle of "building back better" by improving infrastructure and systems to withstand future disasters. Incorporating environmentally sustainable practices further enhances long-term viability and mitigates future risks (UNDRR, 2017).
2. Effective governance and coordination play a central role in reconstruction efforts. Strong leadership is essential for uniting diverse stakeholders, including governmental agencies, non-

governmental organisations (NGOs), and international bodies (Boin et al., 2017). Establishing clear policies and frameworks facilitates coordination and efficient implementation (Alexander, 2002).

3. Adequate funding and resource allocation are also fundamental. National governments, international donors, and private-sector investments must provide sufficient financial support, while efficient resource management ensures timely and cost-effective project completion (Tierney, 2019). The rapid restoration of infrastructure and services is critical for the immediate well-being of affected populations. Essential services, such as water, electricity, and healthcare, should be restored swiftly, emphasising rebuilding quality infrastructure capable of withstanding future disasters (Lindell, 2019).

4. Community involvement and participation significantly enhance the effectiveness of reconstruction efforts. Inclusive planning processes that actively engage local communities to ensure that reconstruction meets their needs and preferences. Empowering these communities fosters ownership and promotes culturally appropriate solutions (Davidson et al., 2007).

5. Capacity building and knowledge transfer are vital components of reconstruction. Providing training and education equips local populations and officials to better manage future disasters. Sharing lessons learned and best practices from previous reconstruction efforts improves resilience and preparedness (Burby, 2003)

6. Health and well-being must also be prioritised. Addressing the psychological impacts of disasters through mental health support services and ensuring access to adequate healthcare are essential for recovery (Neria et al., 2009)

7. Finally, ongoing monitoring and evaluation are necessary to maintain accountability and improve future reconstruction initiatives. Continuous monitoring identifies emerging issues, while impact evaluations provide valuable insights into the successes and limitations of reconstruction efforts (Coppola, 2006).

Extensive research and case studies underscore the importance of a holistic, community-centred, and resilience-focused approach to post-disaster reconstruction, demonstrating its critical role in sustainable recovery and disaster risk reduction. To achieve this, authorities or decision-makers must make significant decisions within a limited time. These decisions play a critical role in successful disaster recovery and are therefore highly important. The following part explains the decision-making processes in the post-disaster recovery context.

2.5 Decision-making in the housing recovery process

2.5.1 Temporary housing process and related decisions

After each disaster, many significant decisions are made by decision-makers which directly or indirectly affect the quality of life of many people. Decision-making in post-disaster housing recovery involves a complex interplay of social, economic, environmental, and technical factors (Smith & Wenger, 2007). Effective recovery models require a balance between speed, sustainability, and long-term resilience to ensure that housing solutions meet both immediate and future needs (Lizarralde et al., 2010). Decision-makers must consider factors such as community participation, resource availability, policy frameworks, and financial constraints to develop strategies that are contextually appropriate. Additionally, integrating risk assessments and resilience-building measures into the recovery process can enhance the adaptive capacity of affected communities. A systematic approach that incorporates data-driven analysis, stakeholder

engagement, and sustainability principles is essential for achieving successful housing recovery outcomes (Afkhamiaghda et al., 2021).

The decision-making process surrounding the implementation and selection of temporary housing involves multiple factors, including sustainability, cultural adequacy, technological feasibility, and community involvement. Various decisions need to be made about temporary housing in the post-disaster context like choosing the location, materials and so on (Félix et al., 2013). There are systematic decision-support systems designed to assist in making informed choices about the use and allocation of temporary housing following disasters. These systems aim to optimize disaster response by considering various factors such as resource availability, affected population needs, and logistical constraints.

One notable example is the Sahana Software Foundation, a non-profit organization founded in 2009 that developed one of the earliest free and open-source software for disaster and emergency management. Their suite of tools includes modules for managing temporary shelters, tracking displaced individuals, and coordinating relief efforts, thereby supporting decision-makers in the effective deployment of temporary housing solutions (Careem et al., 2007).

Another example is the National Shelter System (NSS), developed collaboratively by the American Red Cross and the Federal Emergency Management Agency (FEMA). The NSS is a web-based system that provides comprehensive information on potential emergency shelter facilities, including their location, capacity, and current occupancy status. This system, which later was developed to shape the US National Response Framework, aids disaster relief organizations in planning and operational decision-making related to temporary housing (FEMA, 2011).

Furthermore, several research has been conducted on decision methodologies for determining and optimising suitable post-disaster accommodations. Other research also covers other variables such

as the suitable layouts and orientation of temporary houses, the sustainability factors, materials, location-finding and so on (El-Anwar, El-Rayes, & Elnashai, 2009; Hosseini et al., 2021). These methodologies consider various indicators and contextual factors to tailor temporary housing strategies to specific disaster scenarios, thereby enhancing the effectiveness of the response efforts.

In developing countries, circumstances are usually different, and resource constraints and socioeconomic conditions often influence decisions related to the model of housing recovery and temporary housing. In such countries, the decision-making about temporary housing is a complicated process dealing with post-disaster data collection issues and resource constraints (Afkhmiaghda et al., 2021). Therefore, the need for systematic approaches to decision-making, having accurate evaluations and making correct decisions is essential in these countries.

In Iran, the experience of the previous post-disaster recovery processes studied in the fourth and fifth chapters of this thesis shows deficiencies in making informed decisions about the displaced people's needs and recovery models, which later showed problematic results. Decision-making and planning problems in the same context are also extensively evident in the developing neighbour nations of Iran. Following are some examples of poor decision-makings in the housing recovery processes and the resulting consequences:

In the aftermath of the 2010 floods, Pakistan made significant missteps in the provision of temporary housing. The government and aid agencies decided to build large-scale, centralized relief camps without consulting displaced populations. These camps were overcrowded, lacked proper sanitation, and faced logistical challenges due to their remote locations. Furthermore, the decision to use tents instead of more robust temporary structures, without considering the long-term needs of the population, led to deteriorating living conditions (Encyclopaedia Britannica, 2023).

In Iraq, the response to the 2015 floods in the Kurdistan region highlighted significant errors in temporary housing decisions. The Iraqi government and international organizations failed to consider the timing of their housing response. Many of the shelters were set up late in the flood recovery process, leaving thousands of people to live in inadequate conditions for months. Moreover, many of the shelters were located in flood-prone areas, with no thought to the possibility of further flooding (Abdullah, 2015).

In Turkey, following the 2023 earthquake, the government's ambitious plan to construct 650,000 homes faced delays, with only 201,431 units completed two years later, leaving many survivors in inadequate temporary shelters with poor sanitation and healthcare services. Considering the extensive dimensions of this disaster, using large numbers of temporary houses may have been inevitable. However, a more accurate evaluation of the temporary housing and permanent housing potentials, and improving the decision-making process could have led to more accurate decisions and better results (Toksabay, 2025).

In these examples, a more systematic approach to planning and resource allocation could have expedited construction and improved living conditions for the displaced population and facilitated timely fund allocation and the development of sustainable temporary housing solutions.

2.5.2 Decision-making about using or not using temporary houses

The above examples show some of the general decision-making problems regarding the temporary housing process in the aftermath of disasters in developing Middle Eastern countries. Among the extensive fields of decision-making in post-disaster housing, the focus of this research is specifically on the decisions about using or not using temporary housing units after a disaster and the lack of a systematic approach in this regard.

The literature review shows a gap in this topic not only in developing countries but also worldwide and in some of the most prominent references of the related literature; this decision is simplified in a few paragraphs. For example, according to Davis and Alexander (2015), If there have been plans for recovery and the rapid construction of permanent houses is possible, a two-stage model (excluding temporary housing) can be used, and otherwise, a three-stage model (including temporary housing) should be considered. However, the authors admit the oversimplification in this model and mention that in these models, complex sheltering and housing models are reduced to simple headings. Other references including Johnson and Lizarralde (2012), Fayazi and Lizarralde (2013), Edwards et al. (2019), and Esnard and Sapat (2014) provide insightful facts covering the advantages and disadvantages of temporary houses, and the requirements for a successful temporary housing, but do not offer a systematic solution for deciding when to use them and when not. Our studies show that this is not a simple process, and the correct decision depends on many influencing factors, including a precise evaluation of the rapid permanent housing potential and the temporary housing potential, as well as considering the contextual characteristics and requirements of each approach by including the local decision-makers in the process. The following are some examples of not fully considerate decisions about using or not using temporary houses. These examples are from different countries around the world where the decision not to use temporary houses and instead try to complete permanent houses faster was not a well-informed decision, and using a more systematic approach in decision-making could have had better results.

After the 2004 Indian Ocean tsunami, the Indian government and aid agencies focused heavily on rebuilding permanent housing quickly for displaced populations. However, this rush to complete permanent homes resulted in several problems. First, many of the permanent houses were poorly

constructed due to hasty planning and insufficient consultation with affected communities. Furthermore, many survivors were left in temporary shelters for prolonged periods, with inadequate access to clean water and sanitation (Cheng, 2007).

In the aftermath of the 2010 earthquake in Haiti, millions were displaced, and the immediate response focused heavily on constructing permanent houses. However, the rushed push to complete permanent houses led to significant problems. The construction of permanent housing faced numerous delays due to a lack of resources, coordination, and proper planning (Eaton, 2017). Many displaced people were left in tents for extended periods in unsafe and unsanitary conditions. Furthermore, the permanent housing projects were often ill-suited to local needs, and local communities were not sufficiently involved in the planning process (Cheng, 2007).

After the devastating 2011 earthquake and tsunami in Japan, the government and aid agencies focused on quickly building permanent housing for survivors. However, the permanent housing construction had delays, and many survivors were left in temporary shelters for extended periods, facing overcrowding and a lack of proper facilities (Shiozaki, 2018). The prolonged permanent housing process also failed to take into account long-term community needs, such as rebuilding local economies and ensuring access to essential services (Yang et al., 2024). Following the devastation caused by Typhoon Haiyan in 2013, the government of the Philippines opted to prioritize the construction of permanent homes for displaced populations (Arroyo & Åstrand, 2019). However, the completion of permanent houses was delayed due to a series of obstacles that resulted in the suffering of many survivors. Without proper transitional shelters, displaced families were forced to live in overcrowded conditions in evacuation centres and inappropriate shelters, often without basic sanitation or privacy (Iuchi & Maly, 2016).

In these examples, a more considerate systematic approach to decision-making using a comprehensive decision support system and involving all stakeholders, as well as community consultation, could have led to more optimal results.

Among the studied post-disaster recovery processes, finding the cases in which temporary houses have been used widely while not using them and instead focusing on permanent housing could have better results seems to be impossible. The reason is not sufficient data for evaluation of the potential of related governments and executive institutions in implementing a two-stage housing recovery and successfully removing the temporary housing stage. Nevertheless, as mentioned in Chapter Four, there are successful examples of recovery processes in which removing the temporary housing stage had relatively successful outcomes. However, according to our study, even in successful cases, the decisions have relied more on experience-based decisions by decision-making committees rather than a systematic approach that considers all aspects and influencing factors.

Examining the literature, several decision support frameworks and tools have been developed to aid decision-makers in planning for a successful temporary housing process. These frameworks and tools include allocation and arrangement by El-Anwar, Asce, et al. (2009), location-finding solutions by S. M. Amin Hosseini et al. (2016), material selection by Zea Escamilla and Habert (2015), design and optimisation by Perrucci and Baroud (2020), cultural instructions by Sukhwani et al. (2021), and so on. Nevertheless, examining the literature, there is no decision support system aiding them to make an informed and considerate decision about using the temporary housing stage or removing this stage and going for permanent housing immediately. Examining the literature, including the explained examples and cases, the need for developing a decision-support system for this purpose is evident and crucial.

Considering the importance of making informed decisions about whether to implement the temporary housing stage, the previously mentioned problematic experiences in Iran and similar countries, and the absence of a specific decision-support system (DSS) for this purpose—despite the wide range of post-disaster decision-support tools—the need to develop a reliable DSS to assist decision-makers is evident. In this regard, it is first necessary to study decision-support systems in general. The next step is to review the suitable and most common methods within the post-disaster context. Therefore, the following sections focus on DSS concepts, and the main methods used in post-disaster research.

2.6 Decision-Support Systems

2.6.1 Introduction to decision-support systems

Decision Support Systems (DSS) are integrated tools that assist decision-makers in identifying and solving complex problems by providing data-driven insights. These systems aim to improve the decision-making process by collecting, organizing, analysing, and presenting relevant data. DSS can be categorized into several types, such as data-driven, model-driven, and knowledge-driven systems. Data-driven DSS focus on large databases and offers analytical tools, model-driven DSS provide computational models for decision analysis, and knowledge-driven DSS utilize expert systems or artificial intelligence to suggest decisions based on rules and experiences (Fernando & Baldeovar, 2022).

In general, DSS are built to address ill-structured, complex problems by aiding decision-makers in making informed and objective decisions. The effectiveness of these systems largely depends on

the integration of relevant data, models, and user interfaces, allowing for better decision outcomes (Zopounidis & Doumpos, 2020).

2.6.2 Decision Support Systems in Post-Disaster Recovery

The application of DSS in post-disaster recovery is a relatively recent area of research, yet it is gaining increasing attention due to the complexities involved in disaster management and recovery processes. Post-disaster recovery involves numerous decisions related to resource allocation, infrastructure rebuilding, and managing human and environmental impacts. As disasters can be unpredictable, decision-making in this context must be timely, flexible, and adaptable to changing conditions (Rolland et al., 2010).

According to Rolland et al. (2010), Bénaben et al. (2016) and, Rakes et al. (2014), post-disaster recovery DSS have been used to provide support in several key areas including:

- Resource allocation: Optimising the distribution of limited resources, such as financial aid, materials, and human resources, to affected areas.
- Damage assessment: Analysing the extent of destruction and understanding the needs of affected populations.
- Infrastructure restoration: Prioritising reconstruction activities based on urgency and available resources.
- Policy formulation: Developing recovery policies based on data and predictive modelling.

The complexity of disaster recovery lies in the large amount of data involved, the unpredictability of events, and the need for quick decision-making. Thus, DSS can integrate multiple data sources, including satellite images, environmental sensors, and real-time updates from affected areas, while

providing users with easy-to-understand models to assist in their decisions (Hanashima et al., 2024).

Several methods are particularly important in DSS for post-disaster recovery due to the nature of decision-making in such situations. The most commonly used methods include:

1. **Multi-Criteria Decision Making (MCDM):** MCDM is a decision-making approach that allows for the evaluation of multiple, often conflicting, criteria. In post-disaster recovery, MCDM is used to prioritize reconstruction efforts, balancing factors such as urgency, cost, and long-term benefits (Mushtaha et al., 2025). This method helps decision-makers make well-rounded choices when faced with trade-offs between different recovery objectives (Mohammadnazari, Mousapour Mamoudan, et al., 2022).
2. **Geographic Information Systems (GIS):** GIS is a powerful tool for disaster recovery as it helps visualize the spatial distribution of damages and affected populations. GIS enables decision-makers to map areas of destruction, identify critical infrastructure that needs restoration, and allocate resources more effectively. GIS-based DSS can integrate real-time data to track recovery progress and adjust decisions accordingly (Gerdan, 2018).
3. **Optimization Models:** Optimization techniques are widely used in resource allocation and logistical planning during disaster recovery. Linear programming, integer programming, and network flow models help in determining the best possible allocation of resources to minimize costs or maximize recovery speed. These models are particularly useful when resources are limited and the goal is to find an optimal solution to complex recovery problems (Kamyabniya et al., 2024).

4. **Simulation Models:** Simulation models, such as Monte Carlo simulations, are used to model the uncertainty and variability associated with disaster recovery (Papadopoulos & Yeung, 2001). Two of the widely used simulation techniques are discrete-event simulation (DES) and agent-based simulation (ABS). These models can predict various recovery scenarios under different assumptions, helping decision-makers prepare for possible future events and make more informed choices. They are particularly useful in the early stages of recovery when uncertainty is high (Robinson, 2014).
5. **Expert Systems and Artificial Intelligence (AI):** Expert systems and AI techniques, such as neural networks and machine learning, are applied to analyse large datasets and provide recommendations based on patterns observed in previous disasters. These systems can assist in damage assessment, resource allocation, and policy decision-making. AI systems learn from past data and continuously improve their recommendations, enhancing the decision-making process (Ajaj et al., 2025).
6. **Crowdsourcing and Social Media Analytics:** In recent years, the use of crowdsourced data and social media platforms has been incorporated into DSS for post-disaster recovery. Social media analytics enable real-time data collection from affected communities, offering valuable insights into public needs, areas of concern, and the effectiveness of relief efforts. These data sources are especially useful for real-time decision-making and monitoring during the immediate aftermath of a disaster (Fauzi, 2023).

The methods mentioned above are critical for ensuring effective decision-making in the chaotic environment of post-disaster recovery. MCDM methods ensure that decisions consider multiple stakeholders and objectives and the integration of spatial data through GIS allows for better resource allocation and damage assessment. Optimization models help make the most efficient use

of limited resources, while Simulation models provide a way to prepare for uncertainty, and AI enhances the decision-making process by learning from past events. Finally, crowdsourcing and social media analytics allow for faster and more responsive recovery efforts, ensuring that decision-makers can act on the most current information available.

In post-disaster recovery context, these methods enable decision-makers to make timely, efficient, and informed decisions that can significantly improve recovery outcomes. By combining traditional techniques with modern technologies, DSS can help ensure that recovery efforts are more effective, equitable, and sustainable. Decision Support Systems play a vital role in post-disaster recovery, helping decision-makers address complex, dynamic problems. The continued evolution of these methods and their application in disaster recovery holds the potential to improve the effectiveness and efficiency of post-disaster response, leading to faster and more sustainable recovery (Elkady et al., 2024).

2.7 Conclusion

The literature review in this study focuses on post-disaster recovery, with particular emphasis on the shelter problem. The first sections describe the nature of post-disaster recovery and related concepts, followed by an overview of recent technologies used in post-disaster reconstruction. The third part of the review highlights sustainability as the most comprehensive and meaningful feature of effective shelter. It outlines the key requirements of sustainable reconstruction and temporary housing under the three main pillars: social, economic, and environmental.

The fourth section presents the principles of successful recovery and emphasizes the importance of decision-making in post-disaster recovery. The literature shows that decisions regarding the

characteristics and policies of temporary housing are critical to the recovery process. One of the most fundamental decisions is whether to implement a temporary housing phase at all. Therefore, it is essential to study and apply relevant decision-making concepts and principles.

The fifth section of the literature review examines the decision-making process and its role in post-disaster recovery. This includes a discussion of decision-support systems (DSS), a review of selected disaster recovery cases, and the outcomes of poor decisions related to temporary housing. Commonly used decision-making methods in the post-disaster context are briefly introduced. Chapter Three further explains the Multi-Criteria Decision-Making (MCDM) approach, and the Analytical Hierarchy Process (AHP)—a widely used MCDM method—is selected for developing the DSS in Chapter Six.

Overall, the literature review in this research focuses primarily on the temporary housing process, its key characteristics and theoretical foundations, and the importance of decision-making within this context. The next chapter outlines the research methodology and the requirements for developing the DSS.

Epilogue:

This chapter has provided a comprehensive synthesis of the theoretical frameworks, technological innovations, and decision-making paradigms essential to post-disaster housing recovery. Through a critical examination of academic literature, practitioner guidelines, and real-world case studies, the following chapter objectives have been successfully achieved:

Objective 1: Explored and understood post-disaster recovery, related theories, and concepts, including the sequential stages of sheltering and the socio-technical determinants of successful reconstruction.

Objective 2: Found, reviewed, and compared the latest sheltering and temporary housing technologies, highlighting the operational, logistical, and environmental trade-offs of modular, 3D-printed, and cast-in-place structural systems.

Objective 3: Conducted a critical literature review on sustainability in reconstruction and temporary housing, mapping established sustainability principles, lifecycle considerations, and existing assessment methodologies.

Objective 4: Found and explored the latest post-disaster decision-making frameworks internationally and in similar countries and studied decision-support systems and their usage in the post-disaster context, ultimately identifying a clear gap in systematic tools for evaluating the implementation of temporary housing phases.

By bridging rapid construction capabilities with sustainability imperatives and structured decision-making processes, this chapter has laid the necessary groundwork for the research methodology and system design that follow. The insights and identified gaps directly inform the selection of appropriate analytical tools, guiding the subsequent development of a MCDM framework and the Analytical Hierarchy Process, which will be detailed in chapter 6.

3 Chapter 3: Methodology

This chapter outlines the methodological framework employed to address the research objectives set forth in the introductory chapter. The chapter begins by elucidating the research design and then proceeds to detail the research process.

3.1 Research design

Research design serves as a structured framework for systematically addressing research questions and achieving study objectives. It involves decisions about the alignment of methodologies, theoretical approaches, and research objectives to ensure coherence throughout the study. A robust research design facilitates the logical progression of inquiry, ensuring that each phase of the research builds upon the previous ones. As Kumar (2019) highlights, thoughtful research design contributes to the clarity, validity, and credibility of the study by ensuring that methods and objectives are effectively integrated.

In this research, the research design outlines a structured approach to address the decision-making challenge in post-disaster temporary housing, particularly in the context of Iran. It is divided into three main phases: preliminary studies, problem analysis, and research findings. The study begins with Objectives 1 to 4, which involve background studies and a critical literature review to explore the scope of post-disaster recovery, reconstruction, and temporary housing. These stages aim to identify the research gap, establish objectives, and critically assess existing construction technologies and sustainability principles. Outputs from this phase include an introduction to the research framework and two papers on reconstruction technologies and the sustainability of temporary housing, corresponding to Chapters 1, 2, and 3 of the thesis.

The second phase, focused on problem analysis, includes Objectives 5 to 8, which employ case studies and qualitative research methods. These objectives aim to investigate the processes, technologies, and specific case studies of post-disaster temporary housing, culminating in two research papers. The third phase, under Objective 9, involves developing and validating a decision-support tool (DST) for temporary housing in Iran. This stage integrates focus group and interviews for proof of concept and produces a final paper on a multi-criteria decision-aiding method, forming Chapters 6 and 7, while chapter 8 is dedicated to conclusion. Overall, the research design systematically progresses from foundational studies to applied problem-solving, producing well-defined outputs at each stage. Figure 3.1 presents a research design flowchart that outlines the connections between the research objectives, research processes and methods, research outputs, and the chapters.

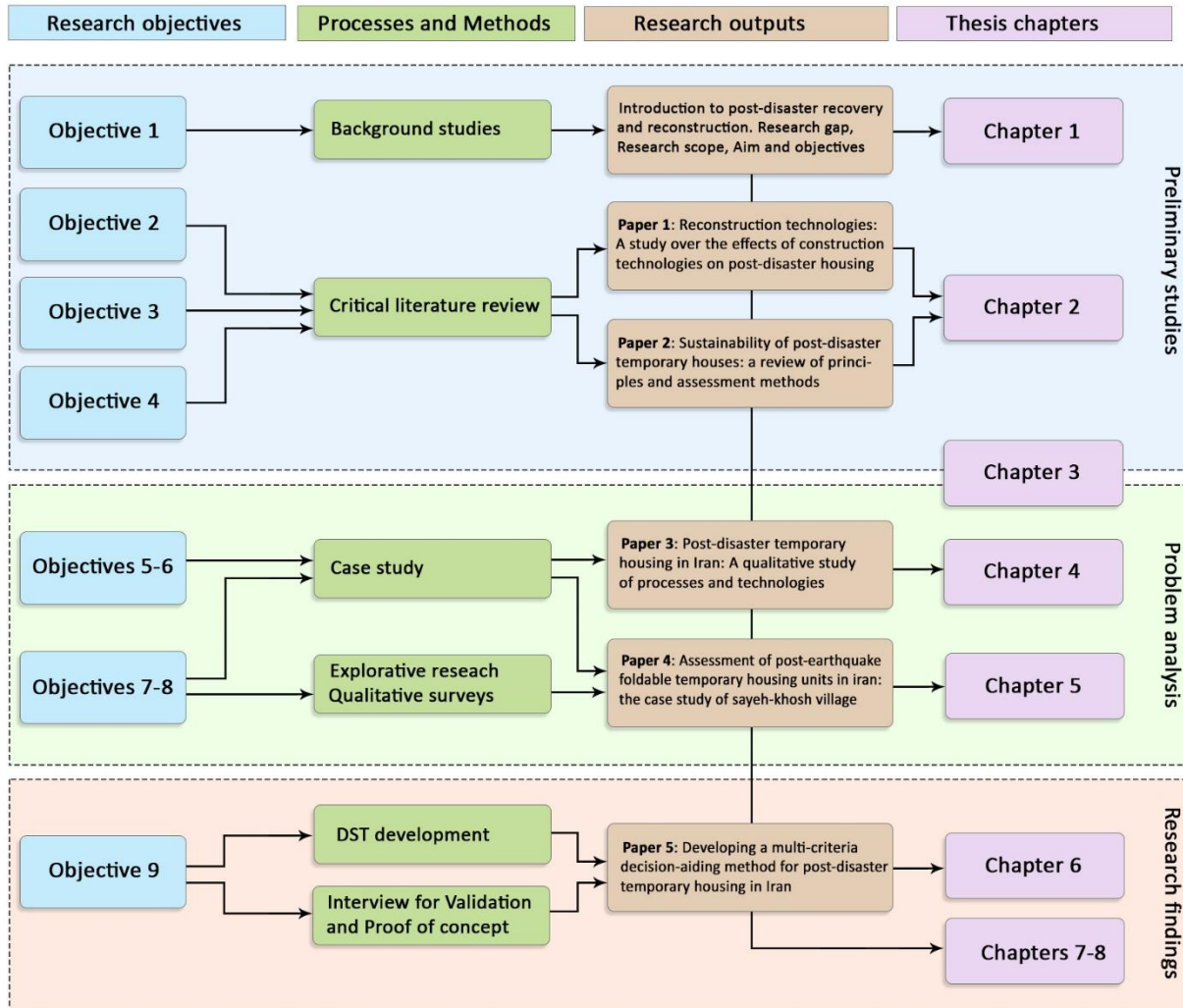


Figure 3.1. Research design flowchart

The research framework follows the "research onion" model introduced and developed by Saunders and Bristow (2023) which is a useful framework for the process of developing and executing a research methodology. It consists of several layers, each representing different stages of the research process. These layers include research philosophy, approach, methodological choice, strategy, time horizons, and techniques and procedures. Each layer of the onion helps to structure and clarify the research design by considering specific methodological elements in a logical sequence. Starting from the outer layer, the model encourages a top-down approach, where

the research begins by identifying the overarching research philosophy, which shapes the research approach.

At the core of the onion lies the techniques and procedures, where the data collection and analysis methods are chosen in alignment with the previous layers. This model provides a comprehensive and systematic framework, ensuring that every aspect of the research process is thoughtfully planned and connected. By guiding the research through a series of methodical decisions, the research onion model helps to build a cohesive research design, aiding researchers in conducting studies that are rigorous, logical, and well-structured. This model forms the basis of the research process utilized in this study.

Figure 3.2. Research onion model introduced and developed by Saunders and Bristow

Source: Saunders and Bristow (2023)

3.2 Research philosophy

This research is developed on a combination of Critical Realism and Positivism philosophies, which, according to Bhaskar (2013), have the capacity to investigate complex social phenomena by examining underlying structures and causal mechanisms. Critical realism is particularly beneficial in contexts where both material and social factors interact. Therefore, given the complex and multifaceted nature of post-disaster recovery and reconstruction, critical realism is an appropriate research philosophy.

In post-disaster contexts, housing recovery is not solely determined by physical reconstruction but is also shaped by social, economic, and political structures (Archer, 1995; Sayer, 2000). For instance, underlying social inequalities and institutional capacity influence resource allocation, affecting both the speed and quality of reconstruction efforts (Pelling, 2003; Wisner et al., 2004). By adopting critical realism, researchers can uncover these deep-seated structures that often remain obscured in positivist approaches, which tend to focus on measurable variables without considering the latent causal layers (Sayer, 2010).

Critical realism's emphasis on stratified reality—comprising the empirical, actual, and real domains—aligns well with the intricate processes of post-disaster recovery, where visible reconstruction efforts (empirical domain) interact with systemic factors such as policy frameworks and community resilience (actual and real domains). This stratification is essential for understanding not only the immediate physical impacts but also the socio-political forces that govern long-term recovery trajectories (Bhaskar, 2013; Oliver-Smith, 2010). Furthermore, critical realism allows for a more nuanced analysis that acknowledges the agency of affected communities, recognizing that they are active participants in shaping recovery pathways (Norris et al., 2008; Tierney, 2020).

The combination of critical realism and positivism allows for a more holistic research approach, wherein quantitative data on physical recovery can be complemented by qualitative insights into the social dimensions of resilience and vulnerability (Oliver-Smith & Hoffman, 2012). This mixed-methods framework is particularly useful in post-disaster studies, as it bridges the gap between structural analysis and practical application, ultimately contributing to more equitable and effective recovery strategies (Pelling & Dill, 2010).

3.2.1 Ontology

Ontology refers to assumptions about the nature of reality and what constitutes knowledge. It addresses questions about what exists and the nature of those entities (Noy & McGuinness, 2001). In this study, the ontology will focus on understanding the nature of the phenomena being studied, considering whether it is seen as an objective reality or a socially constructed one. Considering the process-based nature of his research and its strong dependence on context, it is developed based on a hybrid approach to process-oriented ontology and contextual ontology.

3.2.2 Epistemology

The study of knowledge and its nature plays a crucial role in research as it defines the foundational beliefs about what constitutes knowledge and how it can be acquired, validated, and understood. Epistemology helps to shape the methodological approach, influencing decisions on data collection, analysis, and interpretation. By clarifying the research stance on what is knowable and how knowledge claims can be justified, epistemology provides a framework that underpins the rigour and validity of the study (Crotty, 1998).

Regarding the need to explore how individuals and communities perceive and interpret their housing experiences and needs following a disaster and capturing diverse experiences and insights,

which can inform culturally sensitive and context-specific solutions on the one hand and the aim to provide practical solutions as well as creating actionable knowledge that can be applied to improve post-disaster housing strategies on the other hand, this research is based on constructivism and pragmatism epistemological foundations.

3.2.3 Axiology

Axiology, the study of values and value judgments, plays a critical role in research as it influences how researchers approach their work and make ethical decisions. It addresses questions about what is considered valuable or worthy of pursuit, ultimately shaping the research process and outcomes. Understanding axiology is essential to ensure that personal research biases do not unduly influence research works, and it encourages a reflective approach to the ethical implications of research. As highlighted by Creswell and Poth (2017), axiology is a fundamental aspect of the philosophical foundations that underpin qualitative research, guiding researchers to critically consider the impact of their values on their studies.

Axiology is traditionally divided into two main branches: ethics (which examines moral values) and aesthetics (which explores values related to beauty and art) and according to Schroeder (2008), there are several approaches to understanding and categorising values listed below:

3.2.3.1 *Subjectivism vs. Objectivism*

Subjectivism: This approach argues that values are dependent on individual or collective human preferences, emotions, or experiences. According to subjectivists, something is valuable if people consider it to be so. This means that values vary across different cultures and individuals.

Objectivism: Objectivists believe that values exist independently of human opinions or feelings. According to this view, values are inherent to objects, actions, or states of affairs, and are

universally valid regardless of individual beliefs. This implies that things can be objectively good or bad.

3.2.3.2 Intrinsic vs. Extrinsic Value

Intrinsic Value: This approach differentiates between values that are valuable in and of themselves (intrinsic) and those that are valuable as a means to an end (extrinsic). For example, happiness might be considered intrinsically valuable, as it is often seen as desirable for its own sake.

Extrinsic Value: Extrinsically valuable things are valued for what they bring about rather than for themselves. For instance, money is typically seen as having extrinsic value because it is useful for obtaining other things that are intrinsically valued.

3.2.3.3 Hedonism vs. Pluralism vs. Monism

Hedonism: Hedonistic approaches suggest that pleasure or happiness is the only intrinsic value, with all other values being means to achieve these states.

Value Pluralism: This view posits that there are multiple intrinsic values that are not reducible to a single underlying value. Pluralists believe that things like beauty, knowledge, justice, and love are all inherently valuable, and they cannot be ranked or reduced to a common measure.

Value Monism: Monists believe that all values can ultimately be reduced to a single principle or type of value. For example, a monist might argue that all values can be reduced to the maximization of well-being.

3.2.3.4 Relational vs. Absolute Value

Relational Value: This approach suggests that value arises out of relationships and is dependent on contexts. For example, something may be valuable because of its relationship to a particular person, society, or environment.

Absolute Value: This suggests that certain things have value regardless of context or relations, meaning that they are valuable under all circumstances. This is often associated with moral principles, such as human rights, which are considered universally valuable.

Each of these approaches offers different perspectives on what constitutes value and how we should interpret and prioritise different kinds of values in our lives and societies. In post-disaster research contexts, there are significant aspects of axiology that need to be considered. Concepts like social justice and equity, ethics of care, environmental ethics and sustainability, utilitarianism and cultural relativism which are explained in the following:

Ethics of Care

This approach focuses on relationships, empathy, and the interconnectedness of individuals within communities. It emphasises understanding and addressing the needs of vulnerable populations, such as those affected by disasters. In the post-disaster housing context, the ethics of care can help highlight the importance of providing housing that not only meets basic needs but also supports the well-being, dignity, and cultural needs of affected individuals and families.

Social Justice and Equity

Social justice as an axiology method focuses on fairness, equality, and the equitable distribution of resources. It's concerned with how policies and practices impact marginalised or underserved communities. This approach is particularly relevant in post-disaster scenarios, where unequal access to resources and opportunities often exacerbates vulnerabilities. It can guide you in assessing whether the rebuilding efforts are fair, inclusive, and just for all affected populations.

Environmental Ethics and Sustainability

Environmental ethics emphasises the value of nature and sustainable living, considering both the human and ecological impacts of decisions. This approach is critical in the context of disaster recovery and resilience planning. This method can guide research on sustainable building practices, the use of eco-friendly materials, and the long-term impact of housing on local ecosystems and climate resilience.

Utilitarianism

Utilitarianism is concerned with maximising overall happiness or well-being. In the context of axiology, it can help evaluate the consequences of various housing options based on the overall benefits they provide to the greatest number of people. This approach can be useful for assessing the efficiency and effectiveness of housing solutions, especially when resources are limited. It helps prioritise options that offer the greatest benefits for the affected community as a whole.

Cultural Relativism

This approach values the diversity of cultural norms, beliefs, and practices. It emphasises understanding and respecting the unique cultural contexts of different communities. Cultural relativism can contribute to recognising and integrating the cultural and traditional practices of affected communities into the design and construction of housing solutions.

3.3 Approach to theory development

Deductive and inductive reasoning are essential methods of logical thinking used to derive conclusions and make inferences. Deductive reasoning applies general principles to specific cases to test hypotheses through a top-down approach, while inductive reasoning builds broader generalisations from specific observations following a bottom-up process. Together, they enable rigorous analysis and knowledge-building across various research contexts (Trochim, 2007).

Deductive research, often associated with positivist paradigms, begins with established theories or hypotheses and tests them through empirical observations (Bryman, 2012). This approach seeks to validate or falsify predefined theoretical constructs, aiming for generalisable findings across similar contexts (Yin, 2014). Deductive methods are useful in assessing specific factors, such as the role of governance structures in influencing reconstruction speed or resilience outcomes, which can be measured and compared across cases (Pelling, 2003). However, deductive methods may sometimes fall short of capturing the unpredictable and context-dependent nature of post-disaster environments, where unique local conditions can significantly shape recovery trajectories.

On the other hand, the inductive approach, commonly aligned with qualitative research and interpretive paradigms, involves building theories based on observed patterns or themes within specific cases (Thomas, 2006). Inductive research is particularly valuable in post-disaster recovery as it allows for the exploration of emergent issues and local dynamics that might not fit pre-existing theoretical frameworks. This approach often involves in-depth case studies or ethnographic research, where insights from affected communities and stakeholders inform the development of context-sensitive theories (Oliver-Smith & Hoffman, 2012). The inductive approach is well-suited to understanding the nuances of social factors, such as community agency, cultural resilience, and adaptive strategies, that play crucial roles in recovery processes but are difficult to quantify (Tierney, 2020).

The abductive approach in theory development is another reasoning process that seeks to generate the most plausible explanations for observed phenomena by iteratively moving between data and theory (Tavory & Timmermans, 2014). Unlike deductive reasoning, which tests established theories, or inductive reasoning, which builds theories from specific observations, abductive reasoning begins with surprising or puzzling observations and attempts to create explanations that

best fit the data (Dubois & Gadde, 2002). This approach is particularly useful in exploratory research where established theories may not fully account for observed patterns, and new conceptual insights are needed. Table n summarises the characteristics of each theory development approach.

Table 3.1. Approaches to theory development

	Deduction	Induction	Abduction
Logic	In a deductive inference, when the premises are true, the conclusion must also be true.	In an inductive inference, known premises are used to generate untested conclusions.	In an abductive inference, known premises are used to generate testable conclusions
From/to	Generalise from the general to the specific.	Generalise from the specific to the general.	Generalise from the interactions between the specific and the general
Use of data	Data collection is used to ^{SEP} evaluate propositions or hypotheses related to an existing theory	Data collection is used to explore a phenomenon, identify themes and patterns and create a conceptual framework	Data collection is used to explore a phenomenon, identify themes and patterns, locate these in a conceptual framework and test this through subsequent data collection and so forth.
Theory	Theory falsification or verification	Theory generation and building	Theory generation or modification; incorporating existing theory where appropriate, to build new theory or modify existing theory.

Source: Dudovskiy (2022)

In post-disaster recovery research, the inductive approach is particularly suitable given the complexity and diversity of recovery experiences. Recovery is shaped by a wide range of contextual factors, including social, economic, political, and environmental conditions, that vary significantly across disaster sites (Wisner et al., 2004). An inductive approach enables researchers to uncover context-specific insights that contribute to more flexible and adaptive theories, accommodating the unique characteristics of each disaster setting. This method also allows for a grounded understanding of how communities navigate recovery, fostering theory development that

is responsive to real-world complexities and adaptive to diverse recovery contexts (Paton & Johnston, 2006; Pelling & Dill, 2010). By using an inductive approach, researchers can develop theories that reflect the lived experiences of affected populations, leading to more effective and contextually relevant recovery strategies. Therefore, considering the context-based foundations of this research, it was primarily developed based on an inductive approach to acquire the necessary knowledge of the current situation, the outcomes of the previous housing recovery processes and displaced people's problems. This approach was followed by an abductive research approach, considering the multifaceted and complex nature of the post-disaster recovery and the inability of the established theories to address the evident issues in post-disaster housing processes. The reason for using this approach was to understand the underlying mechanisms and structures while acknowledging the complexity of the whole process.

3.4 Methodological choice

Researchers typically select either mono-method or multi-method approaches depending on the specific research objectives and the scope of the study. Mono-method approaches, such as qualitative interviews or ethnographic observations, are beneficial when aiming for an in-depth understanding of lived experiences and social dynamics within displaced communities (Bryman, 2012; Creswell, 2014). However, multi-method approaches that integrate both qualitative and quantitative methods are increasingly popular as they enable a more comprehensive analysis of temporary housing effectiveness and its impact on the affected population (Yin, 2014). This methodological flexibility supports a more nuanced understanding of how different factors interact in temporary housing contexts post-disaster.

Considering the aim of this research to identify and address a critical issue in the post-disaster housing process, this research focuses on both quantitative and qualitative aspects to provide a

comprehensive understanding. By examining quantitative attributes of shelters and temporary housing, such as technological and physical parameters, alongside qualitative outcomes like the social and psychological impacts on displaced individuals, this study adopts a multi-method approach. This combination allows for an extensive analysis that captures not only the structural and functional characteristics of temporary housing but also the lived experiences and well-being of affected populations, thereby providing insights that can inform more effective and humane housing solutions in disaster recovery contexts.

Developing frameworks and theories in post-disaster recovery and reconstruction requires both qualitative and quantitative approaches to achieve a comprehensive understanding of the processes (Olshansky & Chang, 2009). Therefore, In the first step, the research field was explored and studied through an inductive approach to find the characteristics, qualities and existing challenges in post-disaster housing processes in Iran. After an extensive study of the literature alongside explorative and qualitative research, the gaps and weaknesses were identified. In the next step, the quantitative comparisons between the studied cases contributed to a more specific theory development. Finally, a decision support system was developed to cover both qualitative and quantitative criteria resulting from the previous parts.

3.5 Research Strategies

The selection of suitable methods and methodology is crucial to the study's validity and relevance. Saunders and Bristow (2023) outline eight fundamental methods: surveys, experiments, case studies, archival research, ethnography, action research, grounded theory, and narrative inquiry. Each method is chosen based on the research objectives and questions. Surveys are ideal for quantitative data collection from large samples, while experiments allow for causal testing in controlled environments (Bryman, 2012). Case studies enable a comprehensive understanding of

specific contexts, and archival research uses pre-existing records for analysis of past trends. Ethnography immerses researchers in participants' environments, often through prolonged observation, to capture cultural and social nuances. Grounded theory, designed to generate new theories from collected data, and narrative inquiry, which explores stories and personal experiences, is essential for studies aiming to understand human behaviour (Creswell, 2014; Tashakkori & Teddlie, 2010).

The methodological choice, or research strategy, aligns with the philosophical stance that guides the study. Positivist paradigms, emphasising objectivity and measurement, commonly use surveys and experiments to produce generalisable findings. Interpretivism, with its focus on subjective experience, favours case studies, ethnography, and narrative inquiry for capturing individual and social contexts (Denzin & Lincoln, 2011). Pragmatism underpins action research and mixed methods, allowing flexibility to address complex, real-world issues by combining qualitative and quantitative approaches (Creswell & Poth, 2017). Also, grounded theory is unique in its inductive approach to building theories directly from data, and it can bridge gaps in understanding emerging fields. Selecting the appropriate method depends on the research goals and context, allowing for methodological rigour and alignment with theoretical foundations (Saunders & Bristow, 2023).

In this thesis, the research strategy follows a continuous flow, beginning with a study of the context and the state-of-the-art knowledge on the subject. This is followed by an investigation of the requirements for a successful housing recovery process, an analysis of the problems in previous recovery efforts, and insights from stakeholders. Based on these findings, a framework is developed and ultimately validated.

Therefore, the research strategies were developed to address the research questions through a four-stage process. First, a critical literature review was conducted along the archival research method.

This strategy was used to find the answers to the first, second and third research questions. First to identify gaps and understand the state-of-the-art research and practices in post-disaster reconstruction. Then to study the sustainability concepts in the post-disaster context. Finally, to explore the decision-making processes in a post-disaster context as well as review the decision support systems. In the second stage, case studies were carried out to examine the characteristics of recent reconstruction processes in Iran. The case study method was used for answering the fourth and partly the fifth research questions. The third stage involved a series of interviews with experts to gather their perspectives on current issues in post-disaster temporary housing. This qualitative data collection was used to answer parts of the fifth and sixth research questions. In the fourth stage, using the knowledge acquired from the previous stages, a decision support system was developed and validated to address the final research question in this study. Table 3.2 shows the alignment between the research questions and the research strategies.

Table 3.2. Research questions and strategies alignments

Research question	Research strategy
Q1: What are the latest international innovations and best practices in post-disaster temporary housing?	- Critical literature review on post-disaster reconstruction technologies
Q2: How can post-disaster sheltering be achieved sustainably to avoid recreating future vulnerabilities?	- Critical literature review on sustainability in reconstruction and temporary housing
Q3: Are the available decision support systems able to solve the specific decision-making problems of temporary housing in Iran?	- Critical literature review on the processes in similar countries and the current decision support systems

Q4: How do post-disaster temporary housing processes work in Iran?	- Literature review and archival research - Case studies on the processes and technologies used in the past two decades
Q5: What factors should be considered in the decision-making process?	- Critical literature review - Case study and qualitative data collection to find the current problems in temporary housing and displaced people's needs - Qualitative data collection through interviews with experts
Q6: How can a decision support system be developed to guide post-disaster temporary housing in Iran?	- Developing a DSS using AHP method - Focus group method for validating the DSS

3.5.1 Critical literature review

The case study research method is a qualitative approach used for in-depth analysis of a particular phenomenon within its real-world context, especially when the boundaries between the phenomenon and the context are not clearly defined. This method is particularly valuable in exploratory research, as it allows researchers to investigate complex issues in detail and to generate hypotheses for further study (Yin, 2017). Yin (2017) emphasizes the flexibility of case studies, noting that they can incorporate multiple sources of data, such as interviews, documents, and observations, which help to build a comprehensive understanding of the subject matter. By

focusing on specific cases, researchers can explore the details and contextual factors influencing the phenomenon, making case study research essential for fields that require detailed contextual analysis, such as social sciences and public health (Creswell & Poth, 2017).

In this research, a comprehensive archival review and literature analysis were undertaken in five thematic areas. Initially, theories surrounding post-disaster recovery and reconstruction were explored, identifying leading scholars and foundational works in the field to establish an introductory framework. The second phase involved a thorough examination of current technologies in construction, with particular attention to innovations in temporary housing and their potential applications and impacts. In the third area, the study focused on sustainability, investigating its core principles and evaluation methods. Together, the second and third areas provided a broader conceptual foundation for understanding the intersections of sustainability, post-disaster reconstruction, and temporary housing. The fourth area concentrated on analysing post-disaster recovery processes and predominant challenges specific to the Iranian context. Lastly, the fifth segment of the review engaged with decision-making theories and associated methodologies, providing insight into strategic approaches applicable to post-disaster scenarios.

3.5.2 Case study

Case study research is a widely used method in social sciences and applied fields, enabling in-depth exploration of complex phenomena within real-world contexts (Yin, 2017). It is particularly valuable when the boundaries between a phenomenon and its context are not clearly evident, allowing researchers to investigate both the phenomenon and its underlying contextual factors (Harrison et al., 2017). Case study research typically involves data collection from multiple sources, such as interviews, documents, and observations, to build a comprehensive understanding of the subject (Creswell & Poth, 2017). This method has gained credibility for providing rich

insights and generating new theoretical perspectives, especially in exploratory studies where detailed contextual understanding is essential (Rossman & Rallis, 2017).

In construction research, the case study method is frequently used to analyse specific projects, technologies, and practices, providing valuable insights into factors such as project management, team collaboration, and construction methods (Geraldi et al., 2011). This approach is also effective in examining construction practices in the context of post-disaster recovery and reconstruction, where projects often face unique challenges such as limited resources, urgent timelines, and community needs (Chang et al., 2011). By examining post-disaster reconstruction projects as case studies, researchers can understand how construction practices adapt to these pressures and contribute to the resilience and recovery of affected areas (Bosher & Chmutina, 2017). Case studies in this domain allow for an in-depth investigation of strategies, decision-making processes, and technological applications, offering evidence-based insights to inform future practices in post-disaster settings.

In this research, to acquire a correct understanding of the contextual characteristics, temporary housing issues, and the current procedures, recent post-disaster housing processes over the past two decades in Iran were examined. The specifications of these processes and the technologies used were analysed and compared. Seven cases covering major earthquakes from 2003 to 2023 were studied, allowing for a comparison of the outcomes of various approaches in the temporary housing phase. Concurrently, a recent case of post-earthquake temporary housing in southern Iran was investigated through field studies. This study, conducted in the village of Sayeh-Khosh following the 2022 earthquake, highlighted the latest advancements and ongoing challenges in temporary housing after disasters in Iran. Insights from displaced residents were gathered through

qualitative interviews and narrative inquiry. The findings from these case studies have been presented in two research papers.

These case studies resulted in understanding the current problems associated with post-disaster temporary housing in Iran, which are a significant basis for developing any framework for enhancing the decision-making process.

3.5.3 Qualitative surveying

Qualitative surveying involves gathering detailed information from participants through open-ended conversations. This method allows researchers to deeply explore participants' experiences, perspectives, and motivations, offering rich data that may not be accessible through quantitative methods (Rubin & Rubin, 2012). Interviews can range from structured to semi-structured or unstructured, depending on the research focus and the level of flexibility required. Semi-structured interviews are especially common, as they allow guided questioning while still providing room to explore new topics that may emerge during the conversation. This technique is widely used across disciplines like social sciences, health, and education to understand complex issues more thoroughly (King & Horrocks, 2010).

The interviews in this research were conducted in three stages. First, interviews were carried out with experts in post-disaster reconstruction, including senior officials from Iran's National Disaster Management Organization (NDMO), the Housing Foundation of Iran, and academic staff specialising in reconstruction and retrofitting. These initial interviews were an exploratory process to identify key issues and challenges in housing recovery. The second stage involved field interviews with displaced residents following the 2022 earthquake in Sayeh-Khosh village. Using open-ended questions, these qualitative interviews encouraged participants to share their first-hand experiences through personal narratives. The final set of interviews was conducted to validate the

decision support system developed during the research. In this stage, interviewees included industry experts, such as NGO representatives and independent post-disaster housing practitioners.

3.5.4 Multi-Criteria Decision-Making

Multi-criteria decision-making (MCDM) methods provide structured approaches to evaluate and choose among alternatives when decisions involve multiple conflicting criteria. These methods are widely employed across diverse fields, such as economics, management, and environmental planning because they facilitate a rational and systematic comparison of alternatives. MCDM supports stakeholders in understanding trade-offs between competing objectives, such as cost, efficiency, and sustainability. One of the most widely recognised MCDM techniques is the Analytic Hierarchy Process (AHP), which decomposes complex decisions into a hierarchy of criteria and alternatives. AHP employs pairwise comparisons and a numerical scale to derive weights for criteria and rank alternatives, making it highly intuitive and adaptable for decision-making scenarios (Saaty, 2008).

The strength of AHP lies in its ability to integrate qualitative and quantitative data, enabling decision-makers to incorporate both tangible and intangible factors. AHP is particularly effective in complex environments where trade-offs need to be analysed comprehensively, such as infrastructure planning, resource allocation, and risk assessment. Its structured methodology ensures consistency in judgments, and its ability to involve multiple stakeholders enhances the credibility and acceptance of decisions (Saaty & Vargas, 2012).

In post-disaster recovery scenarios, MCDM methods, including AHP, are invaluable for prioritising recovery efforts, resource distribution, and infrastructure reconstruction. Decision-makers can employ AHP to assess and rank recovery alternatives based on criteria like urgency, cost, social impact, and long-term resilience. For instance, prioritising the reconstruction of

transportation networks versus residential areas requires balancing economic revival and community welfare. AHP also helps stakeholders navigate the complexity of disaster-stricken environments by offering a transparent framework for collaborative decision-making. Research has demonstrated its potential in evaluating recovery strategies to enhance resilience and optimise limited resources in the aftermath of disasters (Mohammadnazari, Mousapour, et al., 2022).

This research employs AHP techniques to develop a reliable decision-support system for selecting the most appropriate post-disaster housing model. By integrating insights from the literature and collected data, an AHP framework is designed specifically focusing on post-disaster temporary housing. Given the complex and multi-faceted nature of decision-making following a disaster, as well as the urgency and long-term implications of such decisions, this method provides a robust foundation for more informed decision-making. It assists decision-makers in adopting a comprehensive and thoughtful approach to addressing post-disaster housing needs.

3.6 Methodology Phases

Phase 1: Critical Literature Review and Theoretical Framework

The research method employed for the initial phase is a critical and comprehensive approach to gathering and synthesizing existing scholarly works related to sustainability in reconstruction and temporary housing. This method involves a thorough search of reputable academic databases to identify relevant articles, books, and other sources. After the initial selection, a secondary screening process is conducted to ensure the inclusion of high-quality and pertinent literature.

To classify the state of knowledge on the subject, the findings are categorized into three subsections: sustainable housing, sustainable reconstruction, and sustainable temporary housing. The main goal of this study is to review sustainability principles and assessment tools in the post-disaster context. For this purpose, the research examines general sustainable housing attributes and assessment systems and then analyses post-disaster construction characteristics alongside related sustainability guidelines and assessment tools.

Phase 2: Historical Case Study Analysis in Iran

The second phase conducts a literature review of the post-disaster housing recovery process in Iran, specifically focusing on the temporary housing stage. Seven cases were chosen, beginning with the 2003 earthquake in Bam, Kerman province, and ending with the 2023 earthquake in Khoy, West Azerbaijan province. The criteria for selecting these seven disasters depended, firstly, on the extent and intensity of the disaster and, secondly, on the unprecedented features of the temporary housing process following the event.

The required data were extracted from relevant literature, including journal papers, books, and governmental reports from the National Disaster Management Organization (NDMO) and provincial authorities. Additionally, non-governmental reports and statistics from the Iranian Housing Foundation—the body responsible for reconstruction and retrofitting—were utilized.

The housing recovery process was studied through a qualitative approach. The consequences of utilizing or omitting a temporary housing stage in the seven cases were analysed to determine the benefits and limitations of each approach. The extracted data from the studied cases are summarized in a comparative format, and the overall housing recovery process time, including all stages, is illustrated in a diagram to demonstrate the impact of omitting the temporary housing stage on the overall recovery timeline.

Phase 3: Empirical Case Study – Sayeh-Khosh

Post-disaster housing recovery is a complex process involving technical, social, and environmental factors that directly impact the lives of displaced people (Johnson & Lizarralde, 2012). Therefore, a qualitative method was chosen for this stage to develop an empirical approach for analyzing the human and social outcomes of the temporary housing process.

Geographical Scope and Site Selection

This exploratory research focuses on Iran's latest temporary housing solutions and their performance. Sayeh-Khosh village in Hormozgan province was chosen for data collection as it had the greatest number of destroyed houses and, subsequently, the highest number of temporary housing units among the areas affected by the July 2, 2022, earthquake (6.1 magnitude).

Due to harsh weather conditions—with summer temperatures often exceeding 49°C—a three-stage housing recovery model using temporary houses was inevitable. This case was unique as it marked the first time prefabricated foldable units were used for nearly all displaced people in a post-disaster situation in Iran. A total of 454 units were dispatched to the village (Charmchian, 2022).

The performance of these foldable units was studied under six primary themes:

Provision time, Transportation, Users' comfort (thermal and acoustic), Design and covered space, Access to services, and Environmental effects and "second life" potential

Data Collection and Ethics

Data were collected through site observations, focus group interviews, document analysis, and post-disaster needs assessments. Following the survey instructions by Fowler (2014) and Fellows and Liu (2021), semi-structured interviews using descriptive, open-ended questions were

conducted. To create a richer picture of the subject, parts of the data were collected in the village's main temporary social gathering space.

Interviews were conducted with 21 displaced people over the age of 18 living in temporary units one month after the earthquake. Additionally, three interviews and surveys were conducted with senior officials from the Housing Foundation and the NDMO. University research ethics were approved, and participants provided consent prior to each interview.

Data Collection Limitations

The process faced certain cultural and social limitations. Displaced residents did not consent to voice recordings; therefore, these interviews were handwritten (interviews with authorities were recorded). Furthermore, due to local cultural sensitivities, only two interviews were conducted with women.

Phase 4: Multi-Criteria Decision-Making (MCDM) Framework

The final phase defines the decision problem: in the absence of urgent evidence for temporary housing (e.g., in mild climates with potential for rapid reconstruction), which recovery policy is superior—two-stage or three-stage recovery?

To address this, the study utilizes the Analytic Hierarchy Process (AHP). MCDM methods allow decision-makers to make informed, transparent, and systematic decisions by balancing immediate shelter needs with long-term community development (Johnson, 2007; Perrucci & Baroud, 2020).

The Analytic Hierarchy Process (AHP)

In this study the AHP process was done through three steps:

Identification: Comparison criteria were first identified through a comprehensive literature review.

Development: An AHP model was developed to structure the criteria and alternatives.

Validation: To ensure robustness, a validation process was conducted using qualitative data collection, including interviews with local experts to refine the model weights and scores.

3.7 Data collection

The data collection process basically involves qualitative methods, such as interviews, focus groups, and observations, or quantitative methods, including surveys, experiments, and secondary data analysis. Researchers carefully design data collection instruments to minimize bias and ensure consistency. Properly collected data serve as the foundation for accurate analysis and interpretation, enabling researchers to contribute meaningfully to their fields (Creswell, 2014). In this research, the required data was collected in four stages using semi-structured interviews and document analysis.

3.7.1 Semi-structured interviews

According to Bryman (2016), interviews are characterised by their flexibility, allowing researchers to adapt questions based on the participant's responses, thus enabling rich, detailed insights. Unlike structured interviews, semi-structured formats use an interview guide with predefined but open-ended questions, facilitating a balance between consistency and adaptability (Kvale & Brinkmann, 2009). This method is particularly effective for understanding participants' experiences, perceptions, and meanings in their own words, which is central to qualitative research paradigms (Creswell, 2014). Therefore, semi-structured interviews are invaluable for studies seeking to explore nuanced human behaviours and social contexts.

Two rounds of interviews were conducted with experts from Iranian disaster management and housing organizations to gather the necessary data for understanding the current housing recovery processes and needs. The interviewees included senior officials and the head of the National Disaster Management Organization (NDMO), as well as reconstruction managers from the Housing Foundation of Iran. A third round of interviews was carried out to collect first-hand accounts from displaced individuals following the 2022 earthquake in Hormozgan Province, southern Iran. Finally, a fourth round of interviews was conducted to validate the developed decision support system.

In Iran, two key decision-making bodies in post-disaster recovery and reconstruction are the NDMO and the Housing Foundation of Iran. Consequently, the expert panel of interviewees was drawn from these two organizations. The interviews in this stage focused on the decision-making processes and the challenges faced in recovery and reconstruction. Given the limited number of experts in these organizations, all available experts were included in the purposive sample. In the third stage, interviews were conducted with displaced individuals, who are the primary users of temporary housing, two weeks after they began living in these shelters. From the relatively small population of Sayeh-Khosh village, 21 individuals consented to participate in semi-structured interviews. These interviews provided valuable insights into the challenges associated with recent temporary housing processes in Iran.

3.8 Research validity and reliability

Research validation ensures the credibility, reliability, and applicability of findings by evaluating the rigour of the methods, data integrity, and consistency of results. It includes practices such as replication studies, peer review, and adherence to methodological standards. Recent advancements in statistical techniques and open science practices have enhanced the validation process,

emphasising transparency and reproducibility (Munafò et al., 2017). Validation is essential for establishing trust in research outcomes, particularly in fields where decisions are based on scientific evidence (Ioannidis, 2018). Data triangulation is one of the methods used to confirm the validity of the research processes.

Data triangulation is one of the methods used to confirm the validity of the research processes. Data triangulation involves combining multiple data sources to ensure a comprehensive and credible examination of a research question. It enhances reliability by cross-validating findings across different methods or datasets, reducing biases inherent in single-source data. Recent studies underscore its value in addressing complex phenomena, particularly in interdisciplinary research (Flick, 2018). Kaplan (2015) Emphasises that triangulation strengthens both qualitative and mixed-methods research by ensuring a holistic view and validating results from multiple angles. This approach is increasingly recognised as a tool for enhancing rigour, particularly in fields like healthcare, education, and social sciences, where multi-faceted perspectives are essential for meaningful insights. This research used methodological and data source triangulation to develop a reliable outcome. In this regard, the decision support system was developed based on the extracted criteria from the literature and insights from the case studies and qualitative surveys. The results were then discussed and validated using the experts' opinions working in the industry.

3.9 Ethical considerations

Ethical considerations are crucial in qualitative research, particularly when employing interview methodologies. Ensuring informed consent is fundamental; participants must be fully aware of the research's purpose, procedures, potential risks, and benefits, and voluntarily agree to participate without coercion (Orb et al., 2001). Maintaining confidentiality and safeguarding participants' privacy are equally critical, necessitating secure data storage and careful handling of sensitive

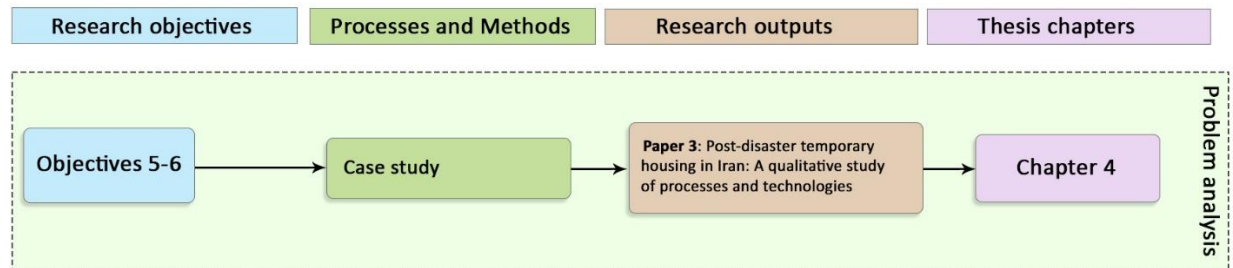
information. Researchers must also navigate power dynamics inherent in interviewer-interviewee relationships, striving to minimize any imbalances that could influence participants' responses. Additionally, cultural sensitivity is essential to respect diverse backgrounds and perspectives, ensuring that the research process is inclusive and respectful (Creswell & Poth, 2017). Adhering to these ethical principles not only protects participants but also enhances the integrity and validity of qualitative research findings.

In this research, ethics approval was first gained from the Human Ethics Committee of Massey University. Following the ethics guidelines, all surveys and interviews were conducted through an entirely informed process. Therefore, all participants expressed their consent before the surveys. Also, the researcher avoided bias, ensuring that the findings accurately represented diverse perspectives, particularly those of displaced populations and decision-makers.

4 Chapter 4: Post-disaster temporary housing in Iran: a qualitative study of processes and technologies

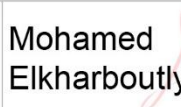
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STATEMENT OF CONTRIBUTION DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

We, the student and the student's main supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the student's contribution as indicated below in the Statement of Originality.

Student name:	Alireza Shamloo		
Name and title of main supervisor:	Dr. Mohamed ElkhARBoutly		
In which chapter is the manuscript/published work?	Chapter 4		
Describe the contribution that the student and members of the supervisory team have made to the manuscript/published work:¹ Writing the original draft, review, and editing by Alireza Shamloo Supervision by the supervisory team			
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Prologue:

This chapter occupies a contextual analytical position within the overall thesis, contributing directly to the development of the proposed decision support system for post-disaster temporary housing. Building on the conceptual and theoretical foundations established in the earlier chapters, this chapter provides a focused investigation into the real-world context of Iran, where recurring seismic events have generated extensive experience in post-disaster housing recovery. Through a qualitative examination of recent case studies, the chapter explores the policies, decision-making processes, and construction technologies employed in temporary housing provision. By identifying patterns of success and failure across different climatic, social, and logistical conditions, this chapter establishes an empirical basis for defining the critical parameters and criteria that inform the design of the decision support system presented in subsequent chapters.

4.1 Introduction

Post-disaster temporary housing is a transitional stage between emergency sheltering and permanent housing. Temporary housing is a significant process directly affecting the survivors' lives and comprises the most living time outside of a permanent house, which may take several months or a few years (Lizarralde et al., 2010). Quarantelli (1995) defined four stages for post-disaster housing reconstruction:

- *Emergency sheltering: a safe place to stay the first hours (or night) after a disaster.*
- *Temporary sheltering: staying at a second house or with a host family or public spaces or tents, and ... for a short time (a few days)*
- *Temporary housing: staying at places like the previous stage or in temporary housing units for months or years with resuming daily activities.*
- *Permanent housing: coming back to new houses.*

Quarantelli believes that these stages are not completely distinctive, and they may be overlapped or mixed with each other. In most cases, the mentioned stages can be simplified into three main stages: temporary sheltering, temporary housing, and permanent housing. Among these three stages, the scope of this paper is focused on the second one (temporary housing), studying the theoretical models and practice.

Temporary housing is considered to have a critical role in the recovery process. Providing a temporary “home” as a safe place for survivors to live in (until the permanent houses are built) is among the first essential steps in the recovery process. This is rooted in the fact that losing a home is more than just a physical loss and affects all aspects of the survivors' lives, from privacy and mental health to security and safety against illnesses and pollution (Bashawri et al., 2014).

Although temporary houses have many limitations and difficulties, sometimes they are the only solution to replace the survivors' feelings of uncertainty with safety and security and let them

regain the needed peace to think and plan for their future (Félix et al., 2013). The experiences of previous disasters have shown that extensive usage of temporary housing facilities is inevitable in some cases, which is mainly dependent on the disaster scale, resourcing shortages, and the weather conditions (Fallahi 2007; Johnson et al. 2006; Lizarralde et al. 2010; Perrucci and Baroud 2020).

The temporary housing phase begins after the emergency/ temporary sheltering stages and usually lasts from six months to 3 years (Perrucci & Baroud, 2020). Temporary housing has two primary options: the first option is using existing facilities, such as available rental accommodations, collective living spaces, re-purposed public buildings, and so on, and the second option is providing temporary houses by building them in place or assembling kit structures or delivering prefabricated units (Lizarralde et al., 2010).

Temporary housing has a significant role in empowering the survivors; nevertheless, previous research shows that high costs of temporary houses can cause dilemmas in their usefulness, and omitting this stage from the recovery process can be more beneficial in some cases, leading to earlier completion of permanent houses (Fallahi & Binesh, 2009; Perrucci & Baroud, 2020). According to Davis and Alexander (2015), this model is called a two-stage housing recovery, which can be achieved by extending the temporary sheltering stage (tents, host family, ...) and using rapid construction technologies (Figure 4.1).

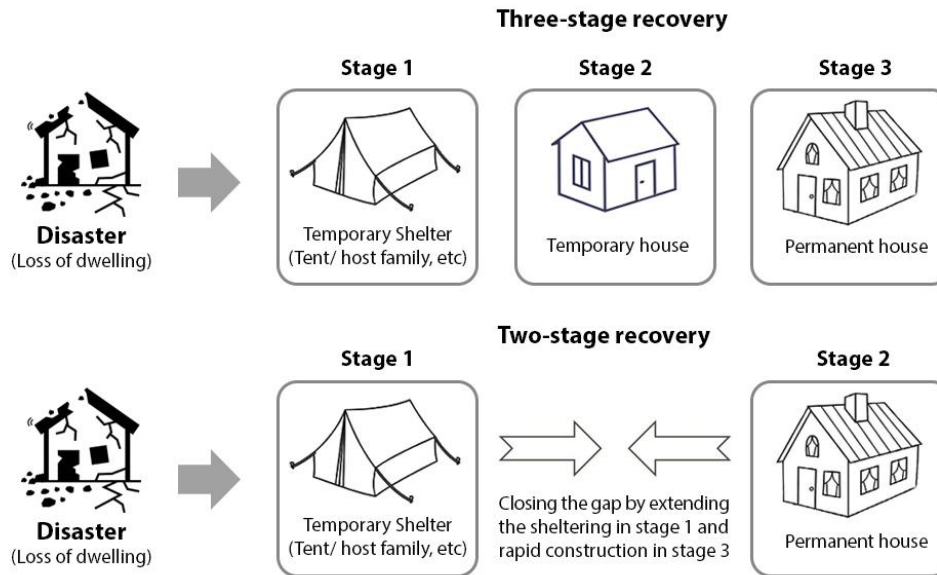


Figure 4.1. Three-stage and two-stage housing recovery models

Source: Based on a concept by Davis and Alexander (2015)

Temporary housing processes have been challenging after recent major earthquakes in Iran and have affected not only the displaced people's quality of life but also the permanent housing process in many cases. This fact is rooted in several parameters that need to be considered carefully during the decision-making process. Firstly, it is important to make a correct decision about using or not using temporary housing, and secondly, it is important to know the required qualities and features in a temporary housing process. According to the previous research by Afkhamiaghda et al. (2021) and Faragallah (2021), these parameters include availability, low costs, transportability, correct location finding, climatic compatibility, thermal and acoustic comfortableness, cultural compatibility, and second-life consideration (reusability and recyclability).

Choosing between the two- or three-stage recovery models, their qualities, and implementation policies is an influential decision that affects the lives of numerous people in their most sensitive times. This paper aims to study the recent post-disaster housing recovery processes in Iran and

determine the main processes, technologies, and effective parameters in failed and successful stories. The rational reasoning in this study stems from the need to clarify the lessons learned from the previous recovery projects to prevent repetitions in the future. The related experiences in Iran are discussed in the following parts.

4.2 Earthquakes and reconstruction in Iran

Iran is an earthquake-prone country located on the Alpine-Himalayan orogenic belt (Jackson & McKenzie, 1984). The high rate of natural disasters in Iran is a result of large populations living on or near active fault zones, the high number of old masonry buildings, and in some cases, the low quality of construction, which is still a prevalent problem despite a 50-year-old building code and executing seismic resistance regulations in the last three decades (Berberian, 2017).

The history of earthquakes in Iran shows extensive devastation and losses. For example, the Bam earthquake in 2003 had an estimated fatality count of around 22,400 people, destroyed almost 93% of the urban buildings, and resulted in the displacement of over 75,000 individuals. The 2017 earthquake in Kermanshah province is another example where more than 600 people died, and 18000 buildings collapsed (Alavi et al., 2018; Eslami et al., 2017; Ramazi & Jigheh, 2006).

Post-disaster temporary housing in Iran has been facing remarkable challenges during the past decades and is still dealing with them. According to the related research, reports, and surveys (Fallahi & Binesh, 2009; Fayazi & Lizarralde, 2013; Hadafi & Fallahi, 2010; S. M. Amin Hosseini et al., 2016), these challenges can be categorised into five main groups:

- *Provision (costs and supplies)*
- *Transportation*
- *Location finding (social issues and resilience issues)*
- *Users' comfort (thermal, acoustic, light, and space)*

- *Second life (collecting issues, reusing, and recycling)*

According to research by Fallahi and Binesh (2009) One of the greatest problems with temporary housing in Iran has been the provision costs and its negative impact on the permanent housing process. Moreover, there are often critical social issues around temporary housing solutions, like neighbourhood problems in campsites, comfort issues, and, in some cases, people's refusal to leave temporary houses at the end of the process (Fayazi & Lizarralde, 2013).

The other significant parameter affecting temporary housing processes is the climatic specification. Iran has various climates, from cold mountainous to hot deserts (both dry and humid) and mild climates (Alijani, 1995). Each climate requires its own architectural considerations established over thousands of years. Therefore, one of the most important factors to be adopted during the reconstruction projects is climatic compatibility, including the correct choice of materials and the thermal performance of the building envelope both in temporary and permanent houses (Celentano et al., 2019). However, according to the displaced people's reports after recent earthquakes, a top-down approach in proposing and implementing typical designs and materials for all regions of Iran has led to climatic incompatibility both in temporary and permanent houses in some cases (Mahdi & Mahdi, 2013; Namin et al., 2021).

4.3 Research method

This paper aims to conduct a literature review on the post-disaster housing recovery process in Iran, focusing on the temporary housing stage. Seven cases were chosen, beginning with the 2003 earthquake in Bam, in Kerman province, and ending with the 2023 earthquake in Khoy, in West Azerbaijan province. The criteria for choosing these seven disasters depended firstly on the extent and intensity of the disaster and secondly on the unprecedented features of the temporary housing process after the disaster.

The required data were extracted from relevant literature, including journal papers, books, governmental reports, including the National Disaster Management Organization (NDMO) and provincial authorities reports, non-governmental reports, and statistics from the Iranian Housing Foundation, which was responsible for the reconstruction and retrofitting of houses.

The housing recovery process was studied through a qualitative approach. The consequences of using or not using a temporary housing stage in the seven cases were studied to determine each approach's benefits and limitations. The extracted data of the studied cases are summarized in a table, and the overall housing recovery process time, including all stages, is shown in a diagram (Fig. 9), which shows the impact of omitting the temporary housing stage on the overall process.

4.4 Findings and discussion

The study of different housing recovery processes reveals that there are many factors affecting the regional provision of temporary houses. Each of the studied cases had a unique characteristic, such as the extent of the damages, climate, the season in which the disaster took place, the geography of the region, the space available for reconstruction, and the logistics associated with the construction of houses. The study also compared the main temporary housing types used after each disaster to find out and classify the most used temporary housing solutions in Iran. The following sections highlight the remarkable issues related to temporary housing analyzed under processes and the technologies used in each post-disaster reconstruction case.

4.4.1 Kerman Province (City of Bam) 2003

Among the seven studied cases, the Bam earthquake was considered the worst disaster in terms of the number of destroyed buildings and the casualties. Over 97% of the houses were destroyed or

severely damaged, and more than 30,000 people (almost one-third of the population) lost their lives (Ghafoory-Ashtiany & Hosseini, 2008).

Processes

The major problem with temporary houses in Bam was their impact on the permanent housing process. It delayed the permanent houses rebuilding. The provision of temporary housing units in Bam was also delayed; it took approximately nine months to complete, and as per Fayazi (2012), the associated costs with temporary housing, the consumed resources, and the time allocated for temporary houses delayed the overall reconstruction process

In addition to this, Fayazi and Lizarralde (2013) mentioned that some of the temporary housing camps constructed after the Bam earthquake remained unoccupied despite the survivors' inevitable need for temporary houses. The main reason for abandoning the temporary houses was their location away from their properties, and the survivors preferred to settle close to their destroyed houses as they were located on their own land.

Technologies

Because of the extent of the disaster, temporary housing units were used widely, including prefabricated and built-on-site units, using various materials and technologies in the camps and yards of the destroyed houses. Figure 4.2 shows some of the utilized technologies and materials.



Figure 4.2. Various technologies were used for temporary housing after the Bam earthquake.

From top left to bottom right: steel structure with masonry walls, Shipping containers, Corrugated sheets, composite 3D polystyrene panel walls to be covered by shotcrete, prefab.

Sandwich panel units, and local organic shelters. *Source: Fayazi (2012), Vojoudi (1383)*

4.4.2 Kerman Province (City of Zarand) 2005

This earthquake destroyed some villages, including Dahuiyeh and Hotkan, which are close to the Kuhbonan fault in central Iran. These villages are located at the heights of the province and have a cold mountainous climate despite the semi-desert climate of the province (Fallahi & Arabpour, 2007).

Processes

The Among the villages and cities affected by the earthquake, the temporary housing stage was completely omitted in the Hotkan village, and this is recognized as an unsuccessful two-stage recovery where the long settlement in tents caused severe troubles for the affected people (Saeedi, 2010).

Technologies

According to (Mahdi & Mahdi, 2013), the tents used for long-term sheltering of the survivors were incompatible with the climatic conditions of the region. Figure 4.3. shows the tents covered tightly with plastic sheets to withstand the harsh cold winter weather.



Figure 4.3. Tents covered with plastic sheets for temporary housing in cold weather. *Source:*
Saeedi (2010)

4.4.3 Lorestan Province 2006

Lorestan earthquake had foreshocks before the main earthquake. This led to the awareness of the people and decreased the casualties to small numbers compared to similar earthquakes in Iran.

Processes

Housing recovery after the 2006 earthquake in Lorestan is known as a successful example of a two-stage reconstruction where authorities decided to avoid using temporary houses (Fallahi & Binesh, 2009). According to Iran's NDMO reports, the influencing factors in this relative success are the following:

The earthquake happened at the beginning of the spring (mild weather conditions), and the reconstruction process was mostly done in favourable weather conditions that let the displaced people stay longer in tents. Omitting the temporary housing stage resulted in the concentration of funds and supplies on the reconstruction of permanent houses. Moreover, the region was naturally rich in construction workforces that contributed to the rapid construction of permanent houses. The Housing Foundation and NDMO organizations of Iran considered incentives (e.g., household appliances) for people to finish the construction of their houses.

Technologies

Temporary houses were not used on a large scale, and the tents provided by the Red Crescent Society were the main shelter until the completion of the permanent houses (Figure 4.4).



Figure 4.4. Typical Red Crescent tents used for temporary sheltering in Iran. *Source: Jafari (2017)*

4.4.4 East Azerbaijan Province 2012

The earthquake happened in the middle of summer in mild weather conditions of the cold climate and destroyed over five thousand houses completely.

Processes

Because of the favourable weather conditions, at first, the Housing Foundation of Iran decided not to use the temporary housing stage. According to the province authorities, this decision led to problems in the next winter and forced the decision-makers to reconsider their decision and provide temporary housing units for the displaced people (Dehghani, 2013).

Technologies

Sandwich panel units were used for people and corrugated sheet curved shelters for the livestock, as most of the people in the region were cattle farmers (Figure 4.5).



Figure 4.5. Left: shelters for preserving animals. Right: Sandwich panel units.

Source: Ghasemi (2013)

4.4.5 Kermanshah Province 2017

Processes

According to Namin et al. (2021), because of the destruction of most public spaces and the extent of the disaster, temporary housing units were used widely after this earthquake. Parts of the units were donated by people, and incoordination in supplying and distribution led to late settlement and people's dissatisfaction in some cases.

In urban areas, because of the high density of buildings, the temporary housing units were placed mostly in campsites or city skirts, and according to a report by the Presidential Center of Strategic Studies (2018), a number of these units were flooded in the following year because of the wrong location finding and lack of resilience considerations (Figure 4.6).

Several factors led to the late completion of permanent houses and long stays in temporary housing units, including the high inflation rate and people's plans for developing their previous houses (Alaedini et al., 2021). The last problem in the temporary housing process was related to the lack of recollecting plans for reusing or recycling the temporary housing units, which led to disorders in the last months.

Technologies

The most used temporary housing units were prefabricated and built-on-site sandwich panel container houses, which are not compatible with the region's cold mountainous climate.



Figure 4.6. Left: wrong location of temporary housing units in Kermanshah; Right: a campsite located beside the destroyed apartments of the city.

Source: Left: Mohammadi (2018), Right: Bakhoda (2018)

4.4.6 Hormozgan Province 2022

The 2022 earthquake in Hormozgan province occurred in the middle of summer in one of Iran's hottest and most humid climates, where the temperature reaches 50 degrees Celsius.

Processes

Because of the climate conditions, the authorities decided to consider the temporary housing stage. The number of destroyed houses was limited, and the available prefabricated units were sufficient for all of the displaced people.

Technologies

Temporary housing units used in Hormozgan had a distinctive feature: For the first time, all temporary housing units were a specific foldable sandwich panel model (Figure 4.7). Because of the relatively small number of destroyed houses, the availability of prefabricated units, and the foldability feature that contributed to more efficient transportation, all temporary housing units were delivered and installed quickly. However, according to the surveys done by the authors, a defect in the design of sealing details led to leakage and air penetration to the units that caused troubles for the users.



Figure 4.7. Foldable temporary housing units were used after the 2022 earthquake in Hormozgan province. *Source: left Emamdadi (2022); right: Authors*

4.4.7 West Azerbaijan Province 2023

Processes

Although the earthquake happened in the middle of winter in a cold mountainous climatic zone, decision-makers decided not to use temporary housing units and start rebuilding permanent houses quickly. This decision caused trouble for people living in tents from the first two months until spring, and by the time of writing this paper (five months after the earthquake), the permanent housing process was still in its early stages.

Technologies

The displaced population was mostly settled in tents located in public spaces such as sports or religious halls or in the outer space of their destroyed houses (Figure 4.8).



Figure 4.8. Using tents and public spaces for extending the temporary sheltering stage and omitting the temporary housing stage.

Source: Left Nazarzadeh (2023), Right: Zeinalabedin pour (2023)

4.5 Summary of Findings

The table below summarises the findings of the previous sections, including the region's climatic classification and the details of the temporary housing process.

Table 4.1. Summary of earthquake data and temporary housing processes in the seven cases.

Year Province Magnitude	Number of reconstruct ed houses	Temporary housing Stage	Climate, Season, and Physiologic Equivalent Temperature (PET) at disaster time	temporary housing process details
28 Jan 2023 West Azerbaijan 5.9	2.15 k	Not used	- Cold mountainous - Winter - Very cold	Displaced people settled in tents and repurposed public spaces.
1 Jun 2022 Hormozgan 5.6	1.2 k	Used	- Hot arid - Summer - Very hot	Using temporary housing units was inevitable because of the hot climate. The first widespread use of foldable temporary housing units.
12 Nov 2017 Kermanshah 7.3	41 k	Used	- Cold mountainous - Autumn - Cold/very cold	Different types of temporary housing units were used in large numbers. Problems with provision and collection.
11 Aug 2012 East Azerbaijan 6.4	17 k	Used	- Cold mountainous - Summer - Comfort zone	Temporary housing units were used because of the cold climate of the region. These units were later used as animal barns.
31 Mar 2006 Lorestan 6.1	30 k	Not used	- Cold mountainous - Spring - Comfort zone	The temporary housing stage was omitted, and permanent houses were completed quickly, known as a successful housing recovery.
22 Feb 2005 Kerman (Zarand) 6.4	15.7 k	Partly used	- Semidesert - Winter - Cold/very cold	Temporary housing units were used except in some villages like Dahuiyeh, where people suffered in winter.
26 Dec 2003 Kerman (Bam) 6.6	30 ~ 35 k	Used	- Warm and dry - Winter - Moderate cold	A large number of prefabricated and built on-site units were used in camps and house yards.

Source: Esmaili (2014); (Housing Foundation of Iran, 2018; World Data, 2023)

4.6 Discussion

The study of the housing recovery programs in the past two decades in Iran reveals that making decisions between using or omitting the temporary housing stage has directly affected the survivors' quality of life during the reconstruction programs. When omitted, the displaced people experience difficulties during the transitional period and, when implemented, cause delays in the permanent housing process (which again affects the displaced people's lives). Therefore, to create a balance between the quality of life during the transitional period and the permanent housing completion pace, it is necessary to consider several factors while deciding on the housing recovery model. The climatic conditions, the basic needs of the displaced people, and the reconstruction potentials, including the supply chain, economics, and construction technologies, are among the considerable parameters.

Another significant fact is that, due to the emergency nature of the circumstances prevailing in the aftermath of disasters, the decision-making process is often influenced by time pressure and social pressure. In such a situation, using decision support tools may help the decision-makers to make more considered decisions and not to repeat past mistakes.

Figure 4.9 shows a comparison between the reconstruction time of the reviewed cases. The longest reconstruction time and settlement in temporary housing units is related to the 2003 earthquake in Bam, followed by the 2005 earthquake in Kerman (Zarand) and the 2017 earthquake in Kermanshah. Comparing the reconstruction time while considering the number of reconstructed houses from table 1 shows the relative pace of reconstruction in each case.

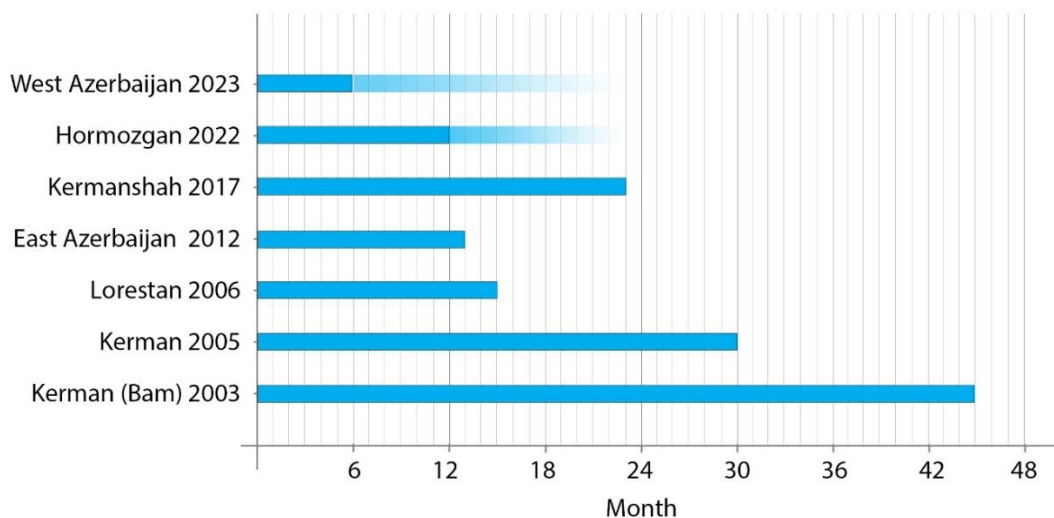


*Figure 4.9. Comparison of the permanent houses' approximate reconstruction time in each studied case
(The last two cases in this chart were under construction at the time of writing this paper)*

Source: data retrieved from Housing Foundation of Iran (2018) and provincial authorities

This study suggests that utilising the latest technologies to build low-cost temporary housing units may decrease the negative financial effects and delays in permanent housing during a three-stage recovery model. Also, increasing the quality and durability of temporary shelters (e.g., tents), in addition to deploying the latest rapid construction technologies, may increase the displaced people's quality of life and decrease the construction time during a two-stage recovery.

4.7 Conclusion

The study of the seven post-disaster reconstruction projects in the past 20 years in Iran shows that the temporary housing stage has been used in four cases: Kerman (Bam), East Azerbaijan, Kermanshah, and Hormozgan, and not used in two cases: Lorestan, and West Azerbaijan; and used partly in Kerman (Zarand). Among the two cases where the temporary housing stage was not used,

The Lorestan case is known as a successful two-stage recovery. However, the decision caused trouble for the displaced people in some cases. The study reveals that, despite the advantages of the two-stage housing recovery shown in the case of Lorestan province, still considering a three-stage model using temporary housing units was inevitable in the other cases. The decision to use or not use the temporary housing stage is, to a great extent, influenced by the climatic characteristics of the region and the extent of the disaster.

The study also shows that the most used temporary housing type in recent disasters in all climatic regions was sandwich panel modular units. These units often suffer from damage and no systematic approach was used for maintenance, repair, collecting, and reusing these units in future disaster relief programs. However, many of them have been used for other purposes in their second life, e.g., as a barn or shelter for animals.

The need for a more comprehensive and advanced decision-making process for choosing the recovery model and technologies is evident within the study. In this regard, further research is suggested to create a decision-support tool for deciding over the two or three-stage recovery model based on the main affecting factors and their weights. Moreover, energy analysis of the most used temporary housing units and finding economical ways to improve their thermal performance and make them compatible with climatic conditions.

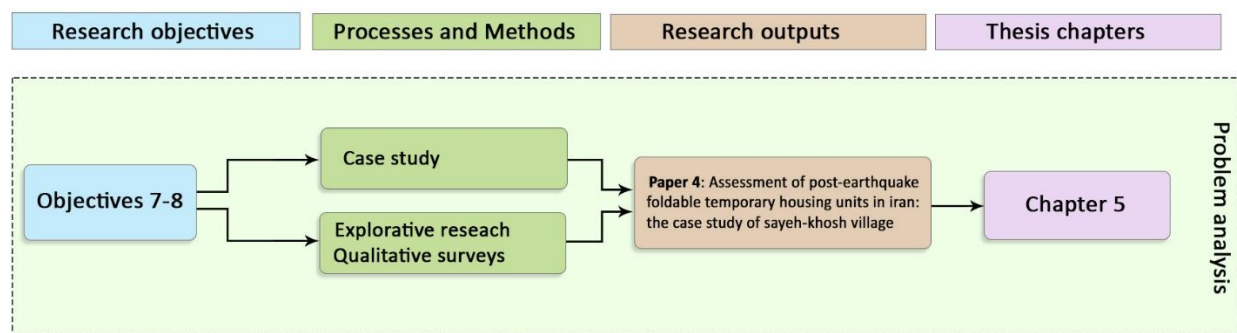
Epilogue:

This chapter set out to investigate and analyse the policies, processes, and technologies used for post-disaster temporary housing in Iran, as well as to evaluate the decisions made in the most significant recent cases. Through a case study of seven major reconstruction experiences, the dedicated objectives have been achieved. The findings reveal the complex interplay between climatic conditions, resource availability, technological choices, and policy decisions in shaping temporary housing outcomes. Furthermore, the comparative evaluation of cases demonstrates how different strategic approaches—particularly the choice between two-stage and three-stage recovery models—directly impact both the quality of life of affected populations and the efficiency of permanent reconstruction. These insights provide a grounded understanding of existing practices and highlight the need for more structured and informed decision-making frameworks, thereby reinforcing the rationale for the development of the decision support system advanced in this thesis.

5 Chapter 5: Qualitative assessment of post-earthquake foldable temporary housing units in Iran: The case study of Sayeh-Khosh village

List of publications constituting this chapter:

- Shamloo, A., Wilkinson, S., Elkharchoutly, M., Domingo, N. (2025). Assessment of post-earthquake foldable temporary housing units in Iran: The case study of Sayeh-Khosh village. International journal of disaster resilience in the built environment. (Accepted)



STATEMENT OF CONTRIBUTION DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

We, the student and the student's main supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the student's contribution as indicated below in the Statement of Originality.

Student name: **Alireza Shamloo**

Name and title of main supervisor: **Dr. Mohamed ElkhARBOUTLY**

In which chapter is the manuscript/published work? **Chapter 5**

Describe the contribution that the student and members of the supervisory team have made to the manuscript/published work:¹

Conceptualization, data curation, visualization, writing the original draft, review, and editing by Alireza Shamloo
Supervision by the supervisory team

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Title: Assessment of post-earthquake foldable temporary housing units in Iran: The case study of Sayeh-Khosh



It is intended that the manuscript will be published, but it has not yet been submitted to a journal

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Prologue

Chapter 5 constitutes a key stage within this thesis by translating the conceptual and theoretical foundations established in the previous chapters into an empirical, field-based investigation. In the context of developing a decision support system, this chapter provides essential real-world evidence on the performance of contemporary temporary housing solutions and the lived experiences of displaced populations. Through an exploratory case study of Sayeh-Khosh village following the 2022 Hormozgan earthquake, the chapter captures both technical characteristics and user-centered evaluations of foldable temporary housing units. The insights derived from this investigation contribute directly to identifying key decision-making parameters and contextual priorities, thereby forming a vital empirical basis for the development and refinement of the proposed decision support system in subsequent chapters.

5.1 Introduction

According to the 2022 global assessment report on disaster risk reduction, the number of disasters has increased worldwide during the last two decades. This fact is rooted in global population growth, expanded settlements, and climate change (Kirsch-Wood et al., 2022). The low resilience rate of communities against natural phenomena such as floods and earthquakes results in the loss of human lives and settlements. Therefore, the need for a safe and secure shelter post-disaster remains inevitable (Badri et al., 2019).

Quarantelli (1995) classified the post-disaster housing process into four stages: emergency sheltering, temporary sheltering, temporary housing, and permanent housing. An emergency shelter is a safe place to be used for hours or over the first night after a disaster. The second stage may last several days and is mixed with emergency sheltering; each of these two stages shades the other. Temporary housing comprises the most living time outside of a permanent house and may take several months or a few years until the permanent houses are retrofitted or rebuilt (Quarantelli, 1995).

Temporary houses may be available, such as rental properties, etc., or unavailable and need to be constructed, such as small cabins, huts, mobile homes, shipping containers, or sandwich panel units. Temporary housing processes using prefabricated units are often controversial in addressing the displaced peoples' needs and are criticized for their unsustainable performance (Lizarralde et al., 2010; Perrucci & Baroud, 2020; Song et al., 2016). Additional costs retarding the permanent housing stage, location-finding difficulties, social disorders, and environmental issues are some evident problems around the temporary housing process using prefabricated units. Therefore, there is a tendency to limit or omit it (Atmaca, 2017; S. M. Amin Hosseini et al., 2016).

Davis and Alexander (2015) believe that in some cases the temporary housing stage can be removed from the housing recovery process; this is provided by extending the temporary sheltering and using the techniques of rapid construction for permanent housing. The main benefit of this two-stage model is concentrating the resources on the permanent housing stage, which contributes to improving the sustainability factors and means that people can recover faster. There are successful examples of two-stage housing recoveries, such as the recovery process after the Lorestan earthquake in Iran in March 2006 that led to the earlier completion of permanent houses (Hadafi & Fallahi, 2010). However, examining the recent disaster relief processes shows that using this model is only possible in some cases, especially when the climate condition is not appropriate, and the extent of the disaster exceeds the public settlement facilities.

According to (Afkhmiaghda et al., 2021; Félix et al., 2013; Hosseini et al., 2019a), where using temporary houses is inevitable, they need to meet several requirements in the following areas:

Costs

Provision or construction time

Safety

Transportability

User comfort (thermal and acoustic)

Design acceptance (functional/cultural)

Access to services

Low negative environmental impacts, reusability, and recyclability (second life)

Moreover, their location should be determined carefully to avoid recreating the vulnerabilities to further probable disasters. According to S. M. Amin Hosseini et al. (2016), the location of

temporary houses also affects public expenditure, delivery time, accessibility, and social acceptance.

5.1.1 Temporary housing in the world, Types, and Characteristics

Temporary housing solutions have a wide variety around the world, from simple shelters covered with plastic sheets provided by UNHCR to self-contained prefabricated units in developed countries. The boundaries between emergency shelters and temporary houses are not distinctive in many cases. Temporary housing is more challenging in developing or poor countries with a high rate of natural disasters where there is a need for high quantities of shelters with a limited budget, like the temporary housing process after the 2010 Haiti earthquake, the 2022 Pakistan floods, and the 2023 Turkey earthquake.

Post-disaster temporary houses are ‘homes’ for the affected families during notable periods of time and should provide an acceptable level of safety, security, and comfort for a reasonable price (Lizarralde et al., 2010). Although temporary houses have many limitations and difficulties, sometimes they are the only solution to replace the survivors’ uncertain feelings with safety and security and let them regain the needed peace to think and plan for their future (Félix et al., 2013).

From another point of view, it is emphasized that a mismatch between the quality of temporary housing and the users’ expectations will result in serious problems. Low-quality temporary housing will result in affected people’s dissatisfaction and social consequences. On the other hand, a fancy temporary house may waste the financial supplies that could accelerate the permanent housing process and make people dependent on them (Ban et al., 2014; Davis & Alexander, 2015). There are examples of displaced people refusing to leave their temporary houses, such as the 1999

earthquake in Turkey, where the government forced people to evacuate their temporary houses by cutting of the utilities and services (Johnson, 2007).

5.1.2 Background of earthquakes and temporary housing in Iran

The highest number of disasters in Iran is related to the earthquakes. Iran is an earthquake-prone country located on the Alpine-Himalayan orogenic belt (Jackson & McKenzie, 1984), and a study of the earthquakes of the past 120 years shows that on average, an earthquake of 7 - 7.4 M occurs every six years, an earthquake of 6 - 6.9 M occurs every year, and an earthquake of 5.5 - 5.9 M occurs every six months which consists a total number of 19 destructive earthquakes (5.5 - 7.4 M) in every six years (Berberian, 2014; Ghassemi, 2016; Pasari, 2023). The high seismic risk in Iranian cities is because of the large populations living on or near active faults, which results in a high rate of damage and fatalities (Firuzi et al., 2022). Despite a 50-year-old building code and the implementation of seismic resistance regulations in the last three decades, damages and casualties of earthquakes are still drastic (Berberian, 2017).

According to Bashiri and Bemanian (2020) and the interviews with Iran NDMO officials, the post-disaster housing process in Iran usually consists of three stages. The first stage is sheltering the displaced people in tents provided by the Red Crescent Society. The second stage is temporary housing, which is done using the available facilities or by building temporary houses. And finally, the last stage, permanent housing, is traditionally managed by the Housing Foundation. In the latest temporary housing programs, the government basically proposed two options to the displaced people: providing them with temporary housing units or giving them the equivalent amount of financial aid for renting an available space. In large-scale disasters like the 2017 earthquake in

Kermanshah, using temporary housing units is inevitable because of the shortage of available spaces.

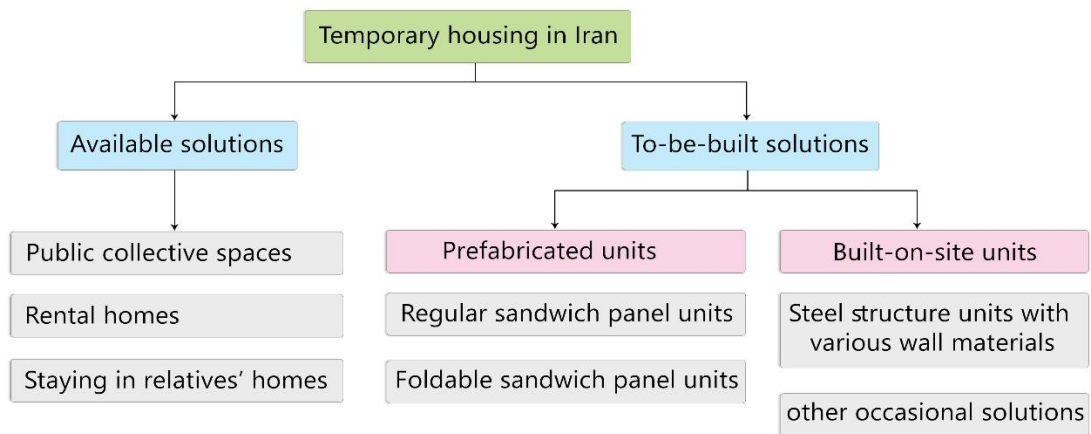


Figure 5.1. General classification of temporary housing solutions in Iran.

The experiences of previous large-scale disasters have shown that temporary housing can be very significant and of high importance. The reason is rooted in five facts:

Intensive earthquakes with a magnitude 6.5 or higher occur almost every year in Iran (Jalali, 2017).

Over 90% of the area is considered an active seismic zone, and there are various extreme climates in different parts of Iran, from cold mountainous to hot deserts, which are considered earthquake hazard zones (Jalali, 2017; Pasari, 2023).

When there is no other option, or they are not sufficient for all, using temporary houses is inevitable. Temporary houses are ‘home’ for the survivors until their permanent houses are ready to use (xe et al., 2015).

Sometimes, the permanent housing process takes a long time to be completed, and people need to use temporary houses for years, like what happened after the Bam earthquake in 2003.

Considering the limited budget for temporary housing and permanent housing, any defect or problem in the temporary housing process can result in irrecoverable consequences (Charlesworth, 2014).

During the past decades, different temporary housing solutions have been used in Iran, from the wooden cabins after the 1990 Manjil–Rudbar earthquake to steel structures and concrete block units after the 2003 Bam earthquake. However, the most used solution in the past decade has been sandwich panel units, like the temporary housing process after the 2017 Kermanshah earthquake (Figure 5.2). The sandwich panel units used in Iran are not a sustainable solution for post-disaster temporary housing. They use steel as the main structure and material, which has a high embodied carbon footprint and is not considered a sustainable material (Lambert, 2016).



Figure 5.2. Temporary housing solutions in Iran. Left: wooden structures, 1990 Manjil-Rudbar. Middle: steel and concrete units, 2003 Bam. Right: Sandwich panel units, 2017 Kermanshah

Source: (Fayazi, 2012; Namin et al., 2021)

5.2 Research method

Post-disaster housing recovery is a complicated process involving technical, social, and environmental factors and directly impacting the displaced people's lives (Johnson & Lizarralde, 2012). Therefore, for this research, a qualitative method was chosen to develop an empirical approach for analyzing the human and social results of the temporary housing process.

5.2.1 The geographical scope of the research:

This is exploratory research about Iran's latest temporary housing solutions and their performance. Sayeh-Khosh village in Hormozgan province was chosen for data collection because of having the greatest number of destroyed houses and, subsequently, the highest number of temporary housing units among the other areas affected by the earthquake.

5.2.2 Case study: Sayeh-Khosh earthquake

Sayeh-Khosh is a small village close to the Persian Gulf in Hormozgan province in the south of Iran. The area experiences a scorching and humid climate, sometimes exceeding 49 °C in summer. There is very little precipitation year-round. The population of Sayeh-Khosh was declared as 1367 people in the 2015 census, and now it is unofficially estimated at around 1800 to 2000 people.

On July 2nd, 2022, an earthquake of 6.1-moment magnitude happened in the western part of Hormozgan province in the south of Iran. It almost destroyed the village of Sayeh-Khosh (IFRC, 2022). According to the report by Iran NDMO, 90% of the houses were destroyed (Nami, 2022).

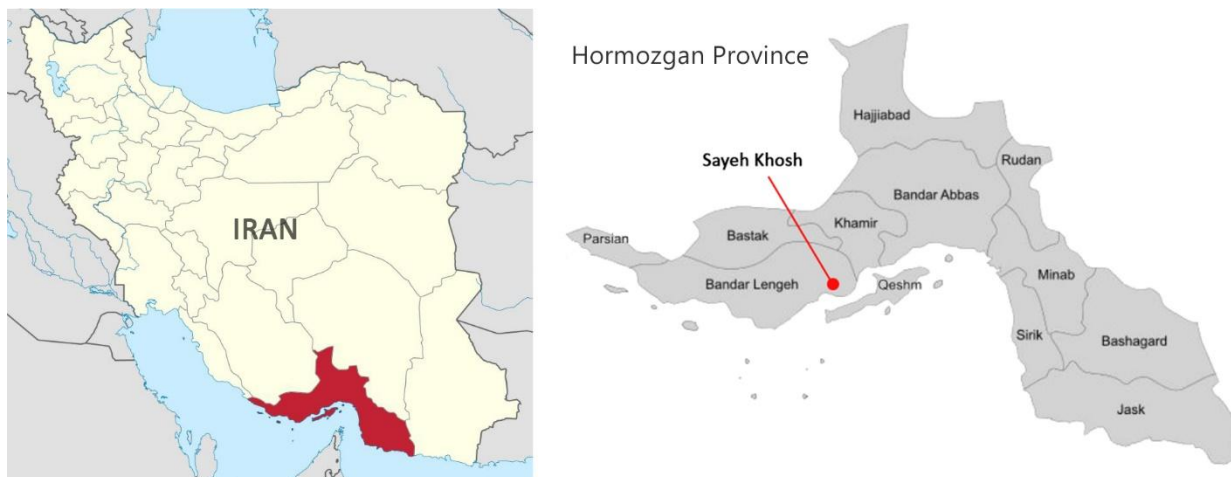


Figure 5.3. The research location: Sayeh-Khosh village, Hormozgan province, Iran

Because of harsh weather conditions, a three-stage housing recovery model using temporary houses was inevitable in Sayeh-Khosh. The location finding for installing temporary housing units was relatively easy as the area is rural with enough safe land close to the destroyed houses. Authorities decided to use the available prefabricated foldable units, and it was the first time that the foldable units were used for nearly all displaced people in a post-disaster situation in Iran. According to the reports, a total number of 454 units were dispatched to Sayeh-Khosh (Charmchian, 2022). Compared to regular sandwich panel units, foldable units had advantages and disadvantages, which are studied and discussed in the following sections.

Based on having access to the required data, we chose six factors to assess the temporary housing process in Sayeh-Khosh from the eight essential factors mentioned in the introduction part. Therefore, the performance of the foldable units was studied under the six themes of:

Provision time

Transportation

Users' comfort (thermal and acoustic)

Design and the covered space

Access to services

Environmental effects and Second life

5.2.3 *Data collection:*

The data was collected through site observation and exploration, interviews with focus groups, document analysis, and post-disaster needs assessment.

Following the survey instructions by Fowler (2014) and Fellows and Liu (2021), semi-structured interviews using descriptive open-ended questions were conducted to allow the respondents to

express their experiences, preferred solutions, and priorities. To make the most out of the interactions through the focus group method that contribute to creating a richer picture of the subject, parts of the data were collected in the village's main temporary social gathering space.

The interviews were conducted with 21 displaced people aged over 18 years, all living in temporary housing units in Sayeh-Khosh village one month after the earthquake. The selection of the interviewees were limited to the available people who were found in public spaces and could be accessed with the least disruption. Also, three interviews and surveys were conducted with three senior officials of the Housing Foundation and the Natural Disasters Management Organization (NDMO) of Iran. The target population and their codes are listed in Table 5.1.

Table 5.1. Focus groups and interviewees coding.

Target population	Codes	Survey type
Displaced people	P1-P21	Semi-structured interviews / Focus group
Senior Officials	SO1-SO3	Semi-structured interviews

University research ethics was approved, and, following these instructions, participants declared their consent before each interview. They were informed that the collected data would remain confidential and anonymous and that they could withdraw from the interview at any time.

Data collection limitations:

The data collection process in Sayeh-Khosh village faced some limitations because of the people's cultural and social characteristics. For example, the displaced people did not consent to record their voices. As a result, all interviews were handwritten (except interviews with authorities that

were recorded). Also, most women were not happy to have interviews, and therefore, only two of the interviews were done with women.

5.3 Findings

Temporary housing units used in Sayeh-Khosh were foldable and were implemented by sandwich panel unit producers in Iran. The main advantages over regular units and any associated problems were analyzed. According to the interviews with the authorities and specialists, foldable units aim to reduce transportation time and cost and decrease the needed storage space.

5.3.1 Provision time

The interviews and reports showed that most of the temporary houses were provided within the first two weeks after the disaster, which is a relatively short time compared to the previous disasters. According to the reports and observations, this record had three main reasons. Firstly, the extent of the disaster and the number of destroyed houses were of a small scale compared to large-scale disasters like the Kermanshah earthquake of 2017 or the Bam 2003, where several thousand temporary houses were used. Secondly, most of these units were prefabricated and stocked, ready to be used; and thirdly, the foldability of the units led to higher transportability and decreased the overall delivery time (Fig. 1). As a result, all of the interviewees were happy with the provision time of their temporary houses.

5.3.2 Transportability

According to the surveys and observations, the main differences between foldable units and non-foldable temporary units are ease of transportation and storage. Figure 5.4 shows the transportation of non-foldable units. However, because of the smaller occupied space, six units can be delivered

by each trailer, while in regular units, this number is not more than one or two. This feature has certain benefits; it accelerates the process of delivering units to the affected areas and decreases the traffic load of the often-crowded roads leading to them. The foldable units also need less storage space while out-of-service, so they can be easily stored and reused. This feature improves the criticized sustainability performance of the temporary housing units.



Figure 5.4. Top right: the bulky shape of the temporary housing units employed in previous disaster relief programs. Top left and bottom: the foldable temporary housing units used in Sayeh-Khosh village.

Source: (Khademosheikh, 2017). (Emamdadi, 2022).

5.3.3 User's comfort (thermal and acoustic)

Sealing (air and water tightness)

Observations and surveys showed that the foldable units had no sealing after unfolding. According to the interviews, most discomfort statements (85.7%) were related to this defect, which resulted in the following issues:

The leakage of cool air and unbearable heat in summer middays (some of the units use two air conditioner units to overcome the heat) and a similar problem in winter.

Penetration of rainwater into the units.

Penetration of dust into the units.

The danger of entrance of snakes and vermin from the floor seams.

High rate of energy consumption, which caused the occasional power outage in critical conditions.

Interviewee P4 mentioned, "Air dust penetrates our unit easily, and I cannot breathe at that time."

According to P20, "This area has dangerous vermin that can come in through the open corners of the units." To overcome this problem, the displaced people used polyurethane foam, plaster, or plastic sheets for sealing (Figure 5.5), which may have consequences, including the unpleasant appearance of the units and difficulties in folding and reusing them.



Figure 5.5. Sealing done by displaced people. Left: polyurethane foam. Middle: plaster mortar. Right: plastic covering.

Source: Authors

Insulation (thermal and acoustic)

Climatic incompatibility is an evident problem with most temporary housing units used in Iran. The same temporary housing units are used in cold and hot climates while they are cold in winter and hot in summer. The insufficient thickness of walls and floor insulation caused thermal and acoustic discomfort in Sayeh-Khosh. As a result, the units needed enormous power for cooling in summer and warming in winter. Moreover, the users' experience shows that the floors are very noisy and disturbing while walking. As a solution, some of the users had covered the floor of their units with blankets and other soft materials.

P17 mentioned, "We experience power outages often. If it happens in mid-day, we should evacuate the units quickly because we cannot tolerate the heat inside". P8 also said, "My biggest problem is the noisy floor. The noisy floor disturbs my sleep when my eight-year-old daughter walks into the unit".

5.3.4 Design and space coverage

Another major area for improvement with these units is space shortage and incompatibility with local architecture. They have a total space of 16 m², which is not enough for most families and forces them to make informal extensions or put their assets outside their units or in their emergency sheltering tents for a long time. Some of the displaced people were unhappy with putting their still-usable stuff beside their units and worried they would be damaged outdoors.

“I am concerned and worried about my furniture and stuff there outside. The harsh sun rays will destroy them in a few months,” P13 said.



Figure 5.6. Informal extensions of the temporary housing units to overcome the space shortage and climate incompatibilities, canopies are made of fabric or palm leaves.

Source: Authors

As a solution for space shortage and social-psychological aspects, some people created semi-open spaces using fabrics or local, sustainable materials such as palm leaves (Figure 5.6). These low-

cost shades made simple covered spaces, protected from the harsh sunbeams of the region, where people could sit in the afternoon and socialise with each other.

5.3.5 Access to services

One of the important problems of the services was power distribution. Also, there was no plan for installing the donated air conditioners, which were installed by the displaced people using non-standard techniques and dangerous electricity connections.

Another problem in services was the lack of sanitary services inside the units and social problems with the public facilities. For example, using shared bathrooms was causing trouble for people, considering their cultural characteristics. Therefore, some people used their relative's facilities of the few undestroyed houses.

“We have to go a long distance to our relative’s house to use their bathroom because we don’t feel comfortable using the provided portable bathrooms,” P15 mentioned.

5.3.6 Environmental effects and second life

In general, temporary housing units are often criticized for their unsustainable characteristics and environmental impacts (Hosseini et al., 2021). The utilized sandwich panel units are made of steel frames and sheets and polystyrene insulation.

Regarding transportation carbon footprint, the foldable units caused a 66% reduction in transportation and related emissions by placing more units in every vehicle. They are also reusable and decrease the need for storage space. On the other hand, they had a high power consumption rate due to weak insulation and tightness. “The supplied air conditioners are not sufficient for

cooling the units. Therefore, we added another air conditioner which was donated to us,” P16 stated. As mentioned in the previous sections, the users overcame sealing issues using polyurethane foam or plaster (Fig. 3). However, these informal solutions can cause limitations and problems in the refolding and reusability of the units. Also, the informal installation of extra air conditioning units damaged the walls of the temporary houses making them less reusable in future disaster relief programs.

5.4 Solutions to the problems encountered – future use of foldable units

It seems that the foldable units’ defects in Sayeh-Khosh are overcoming their advantages and need a revision in design and production. According to the interviews and surveys, a remarkable part of the problems is rooted in the lack of proper sealing, insulation weakness, and space shortage that can be addressed by modifying the details and design. There are solutions for foldable units used for temporary housing worldwide. Modifying the details of the units based on the displaced peoples’ needs can improve their livability and sustainability factors in all social, economic, and environmental aspects.

5.4.1 Assessment Summary

The findings of the research showed that among the six assessed factors, the provision time and transportability were identified as the advantages of the foldable units where prefabrication and the folding feature had contributed to provision time and transportability. The other four factors needed improvement and adjustment. Among these four factors, the solutions devised by the displaced people partly solved some of the comfort and design issues. The performance of the foldable units in the six assessed categories and the related users’ experiences are summarised in the following:

Provision time

The relatively short number of the needed temporary houses and the prefabrication of the units led to shorter provision time, which was vital considering the climatic condition of the region. It was considered a success compared to the previous temporary housing programs. Recollecting and reusing the units, besides building new units for future disasters, seems to be helpful.

Transportability

The foldability of the units led to a higher level of transportability that decreased the provision time and transportation cost. After solving the related issues, foldability can have great advantages in future post-disaster temporary housing processes.

Users' comfort

According to the interviews, the weakest performance of the units was related to the users' comfort, including thermal and acoustic comfort. Considering an appropriate sealing detail for the folding parts and improving the insulation can solve this issue and result in a higher level of users' comfort and less power consumption.

Design and space coverage

Temporary housing units in Iran are used with the same design in all climates. Considering a variety of designs for different climates can improve the performance of temporary houses. Also, the internal space shortage caused troubles for the displaced people. Changing the dimensions of the temporary houses may need remarkable overall budgets, but the users' experience showed that adding a canopy to the outdoor space creates a useful covered space. This feature can be achieved by adding a built-in canopy to future designs.

Access to services

The experience of Sayeh-Khosh showed that cultural incompatibilities can cause trouble for the users of portable bathrooms. Therefore, a revision in the design, location finding, or layout of these facilities is recommended. Moreover, having plans for a safer distribution of electricity, considering the extra AC units added by people, is essential.

Environmental effects and second life

Foldable units are meant to have a better performance in reusability and second life, which is a result of ease of transportation and storage. However, the weaknesses in insulation and detail design led to adjustments done by the users which affected the reusability and also resulted in higher power consumption.

Table 5.2. The main problems in each assessment category and the users' solutions.

Assessment factors	Problem	Solution
Provision time	Lengthy processes of providing temporary houses	Prefabrication of the units led to shorter provision time
Transportability	The bulky shape of regular temporary housing units and	The folding feature improved the transportability
Users' comfort	Critical levels of thermal and acoustic discomfort, low indoor air quality, vermin intrusion	The users used different sealing materials, covered the floor, and added extra air conditioners
Design and covered space	Small indoor space and lack of outdoor coverage	The users added canopies and coverings to the outdoor space
Access to services	The power distribution system and cultural issues with public bathrooms	The users had no appropriate solution for the problem
Environmental effects and Second life	High power consumption of the units and the reusability issues	The users had no appropriate solution for the problem

Source: Authors

According to the additional data collected through additional interviews in 2024, all permanent houses were completed, and most of the temporary houses were removed by the government. The small size of the permanent houses built and the livelihood issues were the main problems remaining in the region.

5.5 Conclusion:

This research assessed the performance of the foldable temporary housing units used after the Hormozgan earthquake in 2022. The assessment was based on six factors extracted from the literature, including provision time, transportability, users' comfort, design, services, and environmental effects. The assessment showed that the utilized foldable units had advantages compared to regular sandwich panel units used in similar previous temporary housing programs. These advantages were categorized under the provision time and transportability parameters. However, despite the mentioned advantages, the displaced people experienced serious problems using these foldable units. The problems were identified through field study and listed in the findings section.

According to the findings of this research, the most stated problems of the users were thermal and acoustic discomfort, and the most influential defects resulting in the discomfort of the users were related to sealing, airtightness, and insulation. The field study also showed that the sealing issues not only affected the users' comfort but also had negative environmental impacts as a result of the increased power consumption and the decreased reusability of the units. Therefore, a revision in detail design of the foldable temporary housing units to improve their insulation and sealing features may have an impact in addressing the issues and making the units more livable in the long term. The other problems identified through the interviews were internal space shortage and access to services.

The users' adjustments to the foldable temporary houses, including the application of sealing materials, covering the interior floor, adding air conditioners, and adding canopies to the exterior area, show the important points that can be improved.

Epilogue:

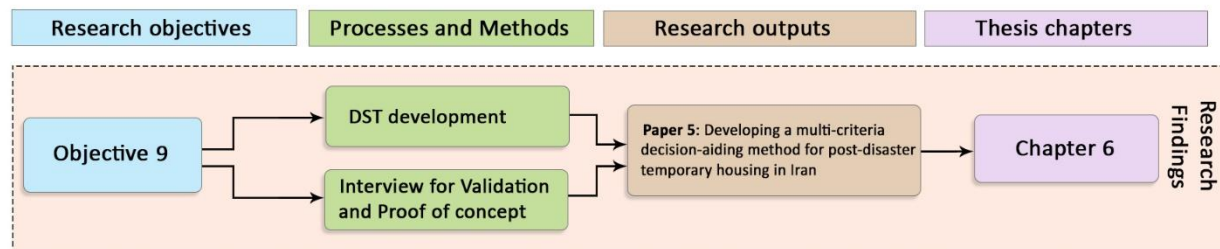
This chapter set out to achieve two primary objectives: first, to conduct an exploratory case study to examine the latest temporary housing solutions implemented in Iran and understand their characteristics from the users' perspectives; and second, to identify displaced people's priorities and the critical parameters required for informed decision-making in post-disaster housing provision. Through qualitative methods including field observations, focus group discussions, and semi-structured interviews with both affected residents and key officials, these objectives have been successfully addressed.

The findings provided a comprehensive evaluation of foldable temporary housing units across key performance dimensions such as provision time, transportability, user comfort, spatial adequacy, access to services, and environmental implications. More importantly, the chapter revealed the priorities and concerns of displaced populations—particularly regarding thermal comfort, sealing quality, spatial sufficiency, and culturally appropriate service provision—which are essential considerations in decision-making processes. These empirically grounded insights establish a clear linkage between user needs and technical criteria, thereby contributing directly to the formulation of effective, context-sensitive parameters for the proposed decision support system.

6 Chapter 6: developing a multi-criteria decision support system for post-disaster temporary housing in Iran

List of publications constituting this chapter:

- Shamloo, A., Wilkinson, S., Elkharchoutly, M., Domingo, N. (2025). Developing a multi-criteria decision-aiding method for post-disaster temporary housing in Iran. International journal of disaster risk reduction. (under review)



STATEMENT OF CONTRIBUTION DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

We, the student and the student's main supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the student's contribution as indicated below in the Statement of Originality.

Student name:	Alireza Shamloo		
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In which chapter is the manuscript/published work?	Chapter 6		
Describe the contribution that the student and members of the supervisory team have made to the manuscript/published work:¹ Conceptualization, formal analysis, software, visualization, writing the original draft and review by Alireza Shamloo Supervision by the supervisory team			
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Prologue

Chapter 6 represents the culmination of this research, where the analytical, theoretical, and empirical findings of the previous chapters are synthesized into a practical and implementable outcome. In line with the overarching aim of developing a decision support system for post-disaster temporary housing in Iran, this chapter focuses on translating identified parameters, user priorities, and contextual constraints into a structured decision-making framework. By integrating insights derived from literature review, expert input, and field-based evidence, the chapter advances from analysis to application. Its significance lies in operationalizing the research contributions into a coherent system capable of assisting decision-makers in selecting appropriate housing recovery models under varying post-disaster conditions.

6.1 Introduction

Post-disaster recovery is a multifaceted process, including different connected stages directly affecting displaced people's lives. Post-disaster sheltering and housing are critical aspects of disaster resilience, shaping long-term recovery outcomes for affected communities. Housing serves as a foundation for personal stability and community recovery, and timely, sustainable reconstruction can mitigate prolonged displacement, economic decline, and social disintegration (Chang et al., 2011). A successful housing recovery requires inclusive decision-making processes that incorporate the needs of marginalized groups, ensuring equitable outcomes (Quarantelli, 1995). Proper planning for post-disaster sheltering and housing reconstruction is crucial for ensuring affected communities' rapid recovery and long-term resilience. Effective planning addresses immediate needs for temporary shelter while laying the groundwork for sustainable and inclusive reconstruction, thereby preventing secondary disasters such as public health crises and economic disruptions (Johnson, 2008; Levine et al., 2007). However, this process involves multiple challenges, including resource constraints, logistical difficulties, and the need to balance urgent response with strategic, long-term rebuilding goals (El-Anwar, El-Rayes, & Elnashai, 2009; Hong, 2017). Planners must navigate complex factors like land availability, regulatory frameworks, cultural preferences, and environmental risks, all while ensuring that reconstruction efforts are resilient to future hazards (S. M. A. Hosseini et al., 2016). Proper planning can significantly enhance the effectiveness of recovery efforts by coordinating diverse stakeholders and aligning reconstruction goals with broader development objectives, ultimately fostering more resilient and equitable communities (Perrucci & Baroud, 2020).

Post-disaster reconstruction has a detailed history in Iran. As a disaster-prone country, Iran experiences devastating earthquakes and seasonal floods every year. Located on the Alpine-

Himalayan orogenic belt, most cities of Iran have experienced intensive earthquakes throughout the past century (Jackson & McKenzie, 1984). Despite the passing of over 60 years since establishing the first Iranian seismic regulations after the 1962 earthquake in Buin Zahra, the number of devastations and casualties is still drastic after earthquakes in Iran (Road, Housing & Urban Development Research Center). As a result, the housing recovery programs, including retrofitting and reconstruction, have been topical and significant during the past decades, and one of the demanding subjects in disaster management has been the sheltering and temporary settlement of the displaced people (Mohtat & Zargar, 2020).

Using or not using temporary houses after the disasters and their consequences have been discussed in several research (Davis & Alexander, 2015; Johnson, 2008; Perrucci & Baroud, 2020). Also, there are several research focusing on the assessment of temporary houses from different perspectives (El-Anwar et al., 2008; S. M. A. Hosseini et al., 2016; Montalbano & Santi, 2023); however, the literature review, along with the experience of post-disaster sheltering and reconstruction in Iran over the past decades, highlights the necessity for a decision-support system to aid local decision-makers in evaluating the benefits and drawbacks of using or not using temporary houses. Such a system would facilitate more informed and effective decision-making in cases where both models of recovery are under consideration (Fallahi & Binesh, 2009; Fayazi & Lizarralde, 2013).

This paper aims to develop a decision-support system for comparing two housing models based on the critical requirements needed for a successful recovery process. The focus of the research is specifically on making decisions about whether or not to use temporary housing in situations where this dilemma is relevant. In this context, the research proposes a multi-criteria decision-making method that enables decision-makers to apply their own priorities while considering the key

success factors highlighted in previous studies. The significance of this research lies in creating a knowledge-based tool to support decision-makers in making fully informed decisions more quickly, helping to avoid repeating past mistakes. This contribution may assist in meeting the emergency needs following a disaster while also considering long-term sustainability requirements.

6.2 Post-disaster Temporary Housing

Transitional and temporary housing terms are used interchangeably in the literature and refer to accommodations provided after a disaster to bridge the gap between emergency shelters and permanent housing solutions. These accommodations are used to offer displaced individuals or families a secure place to stay while permanent reconstruction efforts are underway. Unlike emergency shelters, which are short-term and often basic, transitional housing is intended for longer-term use and is more stable and comfortable, though not permanent. Transitional housing plays a vital role in stabilising communities by offering safe, secure environments that allow residents to regain a sense of normalcy and begin the recovery process. However, managing transitional housing requires strategic planning, community engagement, and sustainability considerations (Johnson et al., 2006).

The significance of temporary housing and transitional shelters as the homes of displaced people for weeks to a few years is evident in the literature (Félix et al., 2013; Lizarralde et al., 2010; Peacock et al., 2018). Also, the experience of recent disasters in developing countries like Iran shows the inevitable need for temporary housing in many cases (Fayazi, 2012; Namin et al., 2021). On the other hand, there are negative aspects associated with temporary housing, resulting in social, economic, and environmental issues. Key challenges with transitional housing involve balancing speed of deployment with quality and ensuring the housing meets the needs of the

community while adhering to budget and logistical constraints. (Fayazi & Lizarralde, 2013; Hosseini et al., 2021; Johnson et al., 2006). Therefore, there is a tendency among the decision-makers to limit or eliminate the usage of temporary houses when possible and replace them with other solutions (Montalbano & Santi, 2023).

Sustainable shelter strategies go beyond immediate relief to include transitional and permanent housing solutions that promote long-term resilience. Well-managed housing initiatives provide physical protection and psychological stability, helping to restore dignity and community cohesion, which are critical for recovery after a disaster. However, poor coordination or mismanagement of housing reconstruction can lead to prolonged displacement, increased vulnerability, and social inequities, especially in marginalized communities (Tafti & Bashiri, 2022). Every reconstruction project is an opportunity to correct the previous vulnerabilities and mitigate future risks. Strategies such as “Build Back Better” (BBB) aim to improve pre-disaster housing conditions and ensure that future risks are mitigated. This is particularly significant in developing countries where housing reconstruction plays a central role in post-disaster recovery. However, it often faces severe challenges due to resource constraints, governance issues, and the need for cross-sectoral collaboration (Mannakkara et al., 2018; Peacock et al., 2018; Tafti & Bashiri, 2022).

According to Johnson et al. (2006), transitional housing solutions can be divided into two major categories listed in Table 1. If there are enough available spaces, using them is the priority, but they are not enough in many cases, and inevitably, new temporary houses need to be built or shipped to the temporary settlement location. This is mainly dependent on the scale of the disaster and destruction extent, the predicted long-term process of reconstruction, and logistical constraints (Lizarralde et al., 2010).

Table 6.1. The two main categories of transitional housing

Transitional housing solutions	Types
Available Temporary housing	- Staying with family or friends - Rented accommodation - Repurposed public facilities
Newly built temporary housing	- Built on-site temporary houses - Prefabricated units/ Shipping containers/ Mobile homes

According to Lizarralde et al. (2010) and Davis and Alexander (2015), when using newly built temporary houses is inevitable, low-cost sustainable solutions should be prioritised. In this regard, the second life of temporary houses should be considered when evaluating their economic and environmental performance. Temporary houses' second life is basically categorised in one of the following options:

- *Repurposed usage (as a storage space or additional space)*
- *Recycling parts and materials*
- *Refurbishing and storing for the subsequent post-disaster use*
- *Used as a rental space owned by the government or the private sector*
- *Used as the core of the permanent house (following pre-plans)*

A successful post-disaster recovery requires careful assessment of the sheltering and housing strategies and their consequences, and making fully aware and foresighted decisions. The literature

shows that involving the local stakeholders in the decision-making process is a key factor for a successful post-disaster recovery (Johnson, 2008; Olshansky Robert et al., 2012).

6.2.1 Temporary Housing Dilemmas

Temporary housing is a controversial issue, primarily due to the typically high costs and the poor social and environmental performance of temporary houses (Johnson, 2007). There are many concepts and designs proposed for post-disaster temporary housing; however, the diversity of recovery scenarios across different cultural, climatic, environmental, economic, and technological contexts makes it impossible to adopt a singular, universally applicable recovery strategy (Davis & Alexander, 2015).

It is emphasised within the literature that in the case of using temporary houses, they should be as low cost as possible, not using many resources and hindering the permanent housing process (Johnson et al., 2006). There are examples of recovery processes like the Bam 2003 earthquake in Iran and the Marmara 1999 earthquake, in which, as a result of poor planning for permanent housing and easing the living conditions in temporary houses (like providing free power and utilities), the displaced people refused to leave the temporary houses years after the disaster. Therefore, having a balance between the costs and quality of temporary houses and proper plans for the transition from temporary houses to permanent houses is crucial (Fallahi, 2007; Johnson, 2002). The other critical factor in temporary housing planning is the location of the temporary houses. Locating temporary houses close to the under-construction permanent houses or in campsites and their arrangement has a significant impact on the quality of life of the displaced people and on the recovery process. There are cases like the 2004 Indian Ocean tsunami in Sri Lanka and Indonesia and the Bam 2003 earthquake, in which the displaced people refused to settle

in the provided temporary houses because of their undesirable location, the design of the houses, or concerns over their livelihoods (Da Silva et al., 2010; Fayazi, 2012).

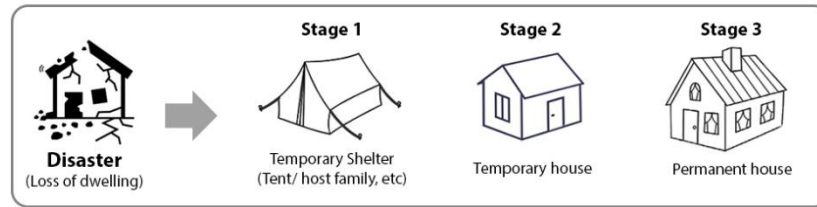
Considering the issues around temporary houses, many researchers have argued the benefits of temporary houses versus their drawbacks and the possibilities of eliminating this stage in the recovery process (Fallahi & Binesh, 2009; Fayazi & Lizarralde, 2013; Johnson, 2008).

6.2.2 The two-stage and the three-stage recovery models

One of the first housing reconstruction models was introduced by Quarantelli (1995), which included four stages: emergency sheltering, temporary sheltering, temporary housing, and permanent housing. In many references, such as internationally recognised reconstruction guidelines, this model is simplified into a three-stage model that starts with using emergency shelters or a host family, followed by a transitional shelter or a temporary house, and finally leads to a permanent house. However, according to Lizarralde et al. (2010), in practice, this three-stage model is not always appropriate, and the process must be defined considering the context and beneficiaries' solutions. Nevertheless, the three-stage housing reconstruction model is still discussed in the literature and used in reconstruction programs worldwide.

Davis and Alexander (2015) compared the three-stage housing recovery model with a two-stage model in which the transitional/temporary housing stage is removed. Figure 6.1 shows this comparison in which the transitional period is covered by extending the

Alternative 1. Three-stage recovery



Alternative 2. Two-stage recovery

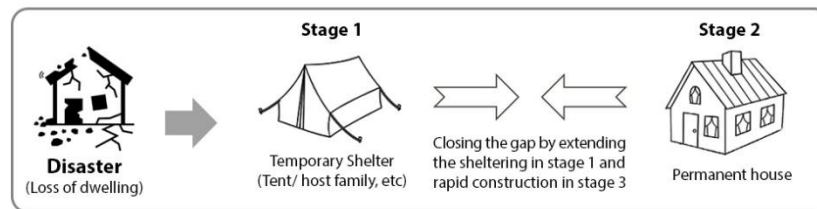


Figure 6.1. The two and the three-stage model concept

Source: Authors

In some post-disaster scenarios, according to the circumstances, there is an urgent need for a three-stage recovery and the use of temporary houses. According to the United Nations Office for Disaster Risk Reduction, UNDRR (2010), these circumstances include the extent of the disaster, the climate conditions, the destruction of infrastructures, and the unavailability of other accommodations (such as rental spaces), especially when, due to the complexities of the reconstruction, there are delays in the permanent housing timelines. In these cases, decision-making is easier for the authorities. But, when the mentioned circumstances are not critical, and the extension of the emergency sheltering stage is conceivable, decision-making about the recovery model becomes more crucial.

6.2.3 Temporary housing experiences in Iran

Iran has experienced devastating earthquakes throughout its history, and the experience of the reconstruction processes of the past decades in Iran shows that temporary housing has been used

widely to accommodate the displaced people following most of the major disasters. The temporary houses used in Iran have come in a wide variety of forms and types, and one of the most prevalent types used in recent years has been prefabricated sandwich panel units, which are criticised for their climatic and environmental performance (Atmaca, 2017; Bashiri & Bemanian, 2020).

Studying the post-disaster recovery processes since the Bam City 2003 earthquake, there have been a few cases where the authorities decided to eliminate the temporary housing stage and implement a two-stage scenario by extending the settlement period in tents and accelerating the permanent housing process. One of the well-known instances was the recovery process after the Lorestan earthquakes 2006, which happened in mild climatic conditions. Ignoring the flaws, this case is mainly considered a successful example of a two-stage recovery program throughout the literature.

On the other hand, according to Farrokhi et al. (2017) and Saeedi (2010), there are also examples of failures in removing the temporary housing stage, which led to severe difficulties for the displaced people and reimposed the costs associated with temporary housing. The first unsuccessful experience was related to Hotkan village after the 2005 earthquake in Kerman province. The permanent housing did not proceed according to the plans. The displaced population spent frigid days of the winter in inappropriate tents, which were covered in plastic sheets to withstand the harsh climatic conditions (Figure 6.2). The other examples of decision-makers' attempts to have a two-stage recovery were the East Azerbaijan province earthquake in 2012 and the West Azerbaijan earthquake in 2023, which again led to problems in the following winter and forced the authorities to use temporary housing units after some months in the first case and resulted in rising demand and price for the rental houses in the second case.



Figure 6.2. The tents were covered with plastic sheets by the users to endure the cold winter

Source: Saeedi (2010)

It must be clearly explained that these success or failure stories are both relative and, according to Lizarralde et al. (2010), basically, there is no recovery program without a transitional housing period. Even in the so-called “Two-stage” recovery, the displaced people are either accommodated in other types of rental or public spaces or in more climate-proof (or winterised) tents, which are both types of temporary solutions. Therefore, it should be explained that the two and three-stage recovery programs in this research specifically refer to having or not having built on-site or prefabricated temporary houses, distinct from winterised tents and public or rental spaces.

Past experiences of post-disaster reconstruction in Iran, disclosed by a thorough review of the literature on post-disaster recovery, shows that determining the qualities and model of recovery during the transitional stage remains a significant challenge in the emergency context following disasters in Iran (Fallahi & Binesh, 2009; Farrokhi et al., 2017; Fayazi & Lizarralde, 2013; Hadafi & Fallahi, 2010). Therefore, a decision support system can help the decision-makers evaluate the most essential requirements of a successful recovery process and compare their importance with each other.

6.3 The conceptual framework of temporary housing

Considering the advantages and disadvantages of temporary housing, it is important to make informed and thoughtful decisions about whether or not to include the temporary housing stage after disasters. To do so, the consequences of each approach must be compared. This requires a clear definition of the properties and characteristics of both sides of the comparison.

On one side is the combination of temporary housing and permanent housing within the three-stage recovery model. On the other side is permanent housing alone, as used in the two-stage model. All relevant qualities, costs, and attributes of both temporary and permanent housing must be identified and considered.

Before any comparison or decision can be made, it is essential to understand the potential of each recovery model and explore all available options. The comparison must involve the best possible version of the temporary-plus-permanent housing model and the best possible version of the permanent-only model.

To achieve this, three key sets of criteria are required. First, what defines good temporary housing? Second, what defines good permanent housing? Third, what defines a successful recovery? The first two sets help identify the best scenarios for each type of housing, while the third set is used to evaluate and compare their outcomes. These sets of criteria may share several common parameters.

A review of the literature shows that many studies have explored the features of good shelters, temporary housing, and permanent housing. This research collects the necessary criteria for comparison, and decisions will be guided by a decision-making panel. Additionally, there is extensive literature on how to form an effective decision-making panel.

6.3.1 Successful transition requirements

To select the suitable alternative for the recovery process among the two mentioned models, the decision-makers need to evaluate them against the requirements of a successful reconstruction process. These requirements are extracted from the literature and thematic analysis of the interviews with the displaced people after the 2022 earthquake in Hormozgan province in Iran, and the experts from the National Disaster Management Organisation (NDMO) of Iran, the Housing Foundation of Iran, and the academic staff of the Reconstruction and Retrofitting School at a local university. They are summarised and categorised into seven main criteria (Table 2). There is an overlap between the references, and different references cover each criterion.

The seven criteria in this analysis are dependent on several qualitative and quantitative requirements that should be considered by the decision-makers while estimating the importance scale of the alternatives during a pairwise comparison. Each requirement has a different weight, and together, they will shape the importance level of the criteria. It should be clarified that these requirements are more general than the characteristics of a good shelter, and they cover the specifications of an ideal housing recovery solution, including sheltering, housing, or the combined methods during the reconstruction process.

Table 6.2. The seven main criteria and their definitions

Comparison Criteria	Definition and indicators	References
Availability and timeliness	Availability of resources, logistics and infrastructure required for temporary housing within a timely manner	Davidson et al. (2007) Nikbakhsh and Zanjirani Farahani (2011) Perrucci and Baroud (2020)
Cost efficiency	Total construction and shipping costs, including infrastructure costs and later transformation costs. Operating costs, including energy consumption costs, maintenance costs, and users' daily commute costs. Cost reduction potentials related to the second life	Lizarralde et al. (2010) Davis and Alexander (2015) Afkhmiaghda et al. (2021) Tafti and Bashiri (2022) Bilau et al. (2017)
Living conditions and Comfort	Supplying the displaced people with physical comfort, including thermal and acoustic comfort, sanitation requirements, and spatial needs. Ease of access to services.	Hosseini et al. (2019) Johnson (2008) Afkhmiaghda et al. (2021)
Socio-cultural and community impacts	Preservation of cultural values and privacy. Providing a feeling of "home". Maintaining social networks and enabling displaced people. Developing social autonomy for social groups.	Lizarralde et al. (2010) Johnson (2008) Fayazi and Lizarralde (2013) Davis and Alexander (2015)
Psychological impacts	Providing mental peace, fostering psychological resilience, and decreasing psychological strains.	Masten and Narayan (2010) Lizarralde et al. (2010) Perrucci and Baroud (2018)
Resilience, Health and safety risks	Providing a safe living space and resilience against hazards and probable natural disasters. Having a secure living space and neighbourhood. Minimising health risks.	Peacock et al. (2007) Mannakkara et al. (2018) Afkhmiaghda et al. (2021) Khorshidian and Fayazi (2023)
Environmental impacts	Pollution (air, noise, and visual), environmental impacts, and waste production. The amount of material and energy consumption. Level of using locally available resources. Second-life potentials (repurposing, reusing or recycling).	Hosseini et al. (2019a) Perrucci and Baroud (2020) Lizarralde et al. (2010) Félix et al. (2015)

6.4 Research Method

Examining the literature on post-disaster housing in Iran, the decision problem is defined based on the following questions. After a new disaster, if there is no clear evidence of an urgent need for temporary houses (e.g. in a mild climate with potential for rapid construction), which housing recovery policy will work better, the two or the three-stage recovery? To what extent is having the temporary housing stage recommended?

Considering the diverse and qualitative nature of the housing recovery requirements and their mutual impacts on each other, decision-makers are confronting multiple criteria that must be evaluated and prioritised. Using Multi-criteria decision-making (MCDM) methods in post-disaster scenarios allows decision-makers and stakeholders to make informed, transparent, and systematic decisions, improving community resilience and reducing recovery times by ensuring that housing solutions are sustainable and aligned with local needs. This approach addresses complex challenges by balancing the immediate need for shelter with the long-term goals of community development. (Johnson, 2007; Perrucci & Baroud, 2020).

6.4.1 Multi-Criteria Decision-Making

Multi-criteria decision-making (MCDM) is a methodological framework employed to address complex decision-making scenarios where multiple, often conflicting criteria must be considered. MCDM aids decision-makers in evaluating and prioritising different alternatives based on various qualitative and quantitative criteria, ensuring a balanced and well-informed decision process. The foundational premise of MCDM is to address and mitigate the limitations inherent in unstructured individual or group decision-making processes by facilitating structured comparisons and rankings of alternatives, which is particularly useful in fields such as environmental management, resource allocation, and disaster recovery (Hwang & Yoon, 1981; Saaty, 1980). MCDM methods provide

robust tools for decision-makers, each offering unique strengths depending on the decision context (Figueira, Greco, & Ehrgott, 2005).

One of the well-known MCDM methods is the Analytic Hierarchy Process (AHP), which aids in structuring complex decisions by breaking them down into smaller, manageable components and ranking alternatives based on pairwise comparisons. AHP enables decision-makers to prioritise alternatives based on multiple criteria. This method is widely used due to its ability to handle both qualitative and quantitative data, making it suitable for complex decision-making scenarios. It has been widely used in various fields, including strategic planning, politics and project prioritisation (Saaty & Vargas, 2012).

6.4.2 Analytical Hierarchy Process

AHP is an effective tool for analysing multiple criteria to support decision-making processes. This methodology provides a structured decision-making framework by representing the problem in a hierarchical format. Developed by Saaty (1984), the AHP incorporates qualitative judgments from experts and users, employing a nine-point scale to establish criteria priorities through a pairwise comparison matrix. AHP decomposes a decision problem into a hierarchy of sub-problems, which are analysed independently. Pairwise comparisons of criteria and alternatives help calculate weights and scores for a comprehensive comparison.

AHP is particularly valuable in cases where multiple stakeholders are involved, as it facilitates consensus-building by offering a transparent and systematic way to integrate diverse perspectives and preferences. This method is widely respected across industries for its ability to enhance decision quality while ensuring consistency and clarity in the decision-making process (Vaidya & Kumar, 2006).

In this study, comparison criteria were first identified through a comprehensive review of the literature. Subsequently, an AHP model was developed and detailed. To ensure the robustness of the model, a validation process was conducted using qualitative data collection. This involved interviews with local experts whose insights were used to refine the model further.

6.4.3 Designing the process

Following the instructions by Saaty (2008), the decision problem is defined, which is, in this case, deciding whether to use or not to use the temporary houses after a disaster in Iran. Next, the hierarchy tree is constructed by breaking the problem into goals, criteria, and sub-criteria. (Figure 6.3).

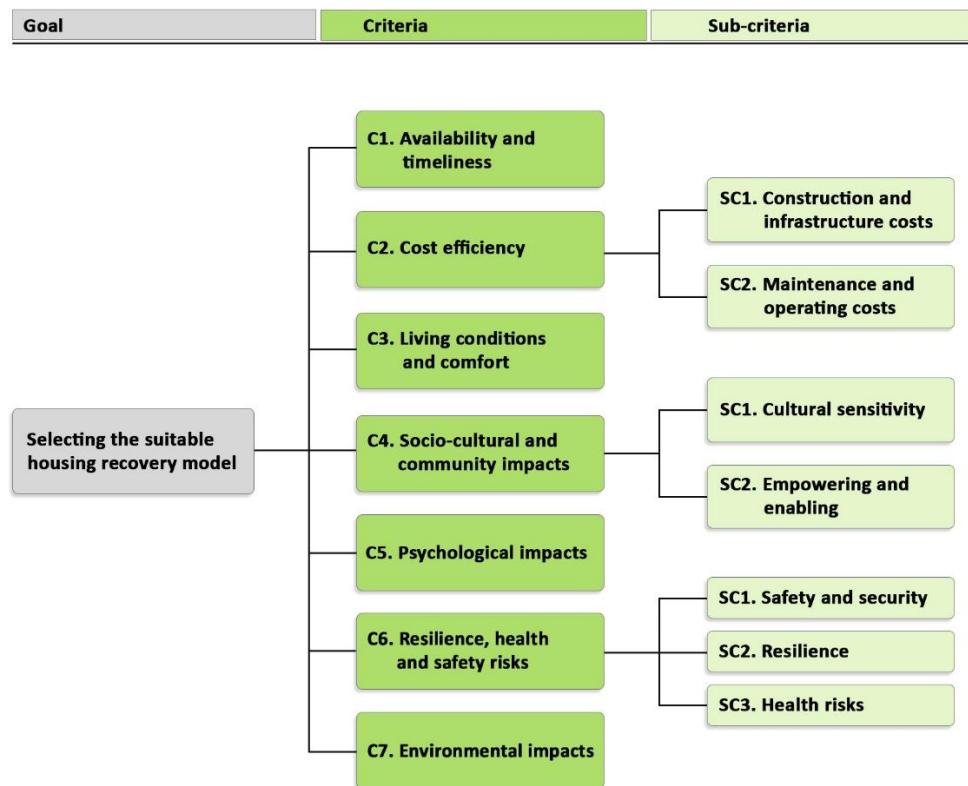


Figure 6.3. The AHP model for choosing the better housing recovery model based on six comparison criteria

Source: Authors

In the next step, the decision-makers make a pairwise comparison between the six criteria and determine the importance of each criterion over the other one. The comparisons utilise a numerical scale to quantify the relative importance or dominance of one element over another with respect to a particular criterion or property (Saaty, 2008). Decision makers express their preferences verbally, which are then translated into numerical values. The numerical scale serves merely as a tool to convert verbal judgments into quantifiable data. Several scales are available in the literature, such as the Saaty fundamental scale (Table 2).

Table 6.3. The Saaty Scale

<i>Saaty's scale</i>	<i>Definition</i>	<i>Explanation</i>
1	Equal Importance	Two activities contribute equally to the objective
	Weak or slight	
2	Moderate importance	Experience and judgment slightly favour one activity over another
3	Moderate plus	
	Strong importance	Experience and judgment strongly favour one activity over another
4	Strong plus	
	Very strong	One activity is favoured very strongly over another
5	Very, very strong	
6	Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation
7		
8		
9		

Source: (Saaty, 2008)

After the completion of each comparison matrix, the consistency index is calculated to show the consistency of the decision-makers' preferences, which according to (Saaty, 2008) should be under 0.1. The resulting pairwise importance values are then processed using AHP analysis software,

and the weight of each criterion is determined as a fraction of the total weight of one. In the next step, the comparison process between the two alternatives starts with determining the details of each housing model. For each model, these details include the type and specifications of the emergency shelters, the temporary houses (or the alternative solution such as winterised tents or repurposed public spaces) and the permanent houses. When added together, these details should include all qualitative and quantitative specifications of each housing scenario. Having these details, the characteristics of each alternative are ready for comparison. The reason this model includes permanent housing in the comparison is the connected nature of the housing reconstruction processes. For example, if the utilised temporary houses in the three-stage model are the core for the permanent houses or if their materials are reused, this will decrease the overall cost of that scenario.

The steps of pairwise comparisons, analysing the derived data using AHP software and giving weight, are done seven more times to compare the two alternatives against one criterion each time. These comparisons will determine the priority of each alternative against each criterion. By multiplying the priority of an alternative against a criterion in the weight of that criterion (calculated in the first step), the global priority of that alternative against that criterion will result. Finally, by adding the global priorities of each alternative, the final priority of each alternative is obtained.

6.5 Process example

In this example, which is based on data from the 2012 earthquake in the East Azerbaijan province and using hypothetical weightings, the AHP workflow for deciding about the recovery model is explained.

In the first step, the qualities and technologies of each model are defined. In this case, the 12 m² Red Crescent tents were used for temporary sheltering and prefabricated 15 m² sandwich panel units were used for temporary housing. The first alternative (the three-stage model) consists of using tents, followed by prefabricated units, leading to permanent houses, and the second alternative (the two-stage model) consists of using tents for a longer time and completing the permanent houses sooner.

In the next step, the decision-makers make pairwise comparisons between the seven criteria listed in the AHP model. This comparison is also made between each sub-criteria to find the importance level of them. Table 3 shows an example of the pairwise comparison.

Table 6.4. Pairwise criteria comparison

	Availability and timeliness	Cost efficiency	Living conditions and comfort	Socio-cultural and community impacts	Psychological impacts	Resilience, health and safety risks	Environmental impacts
Availability and timeliness	1	1	2	3	1	1/2	3
Cost efficiency	1	1	2	3	1/2	1/3	3
Living conditions and comfort	1/2	1/2	1	2	1	1/5	2
Socio-cultural and community impacts	1/3	1/3	1/2	1	1/2	1/3	1
Psychological impacts	1	2	1	2	1	1/2	3
Resilience, health and safety risks	2	3	5	3	2	1	5
Environmental impacts	1/3	1/3	1/2	1	1/3	1/5	1

After completing each set of comparisons, the consistency ratio is calculated. According to Saaty (2008), consistency ratio should be less than 0.1, which in this example is 0.03 and acceptable. If the calculated consistency ratio was over 0.1, the comparison process should be revised. Similar comparisons are made for the sub-criteria of each criterion, and related software calculates the weight of each criterion based on the resulting matrix. The new Hierarchy with assigned weights is shown in Figure 6.4 In the next step, the two alternatives are compared with respect to each criterion/sub-criterion.

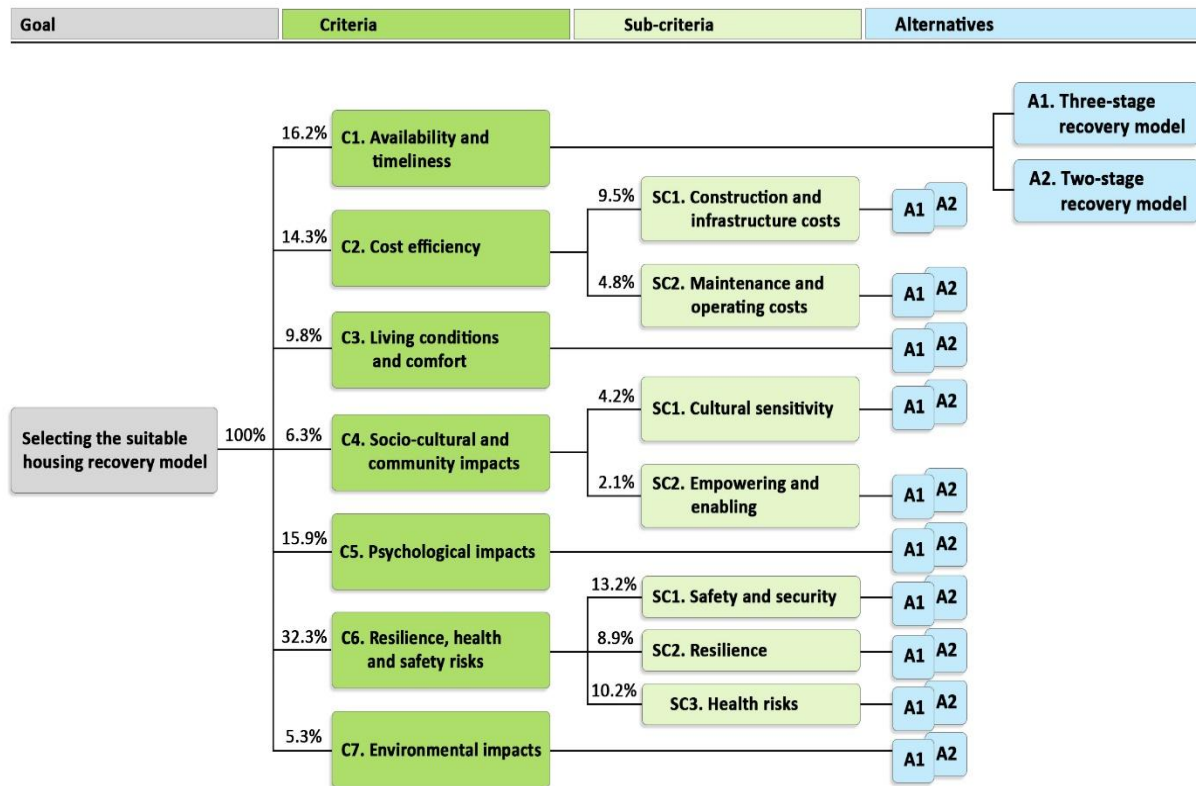


Figure 6.4. Pairwise comparisons based on the assigned weights

Source: Authors

Considering the attributes of each alternative, the decision-makers estimate the alternative's performance concerning each criterion and give their opinion about its priority against the other

alternative. Table 5 shows the exemplified comparison between the two alternatives concerning the first criterion (availability and timeliness).

Table 6.5. Comparing the alternatives concerning the first criterion (availability and timeliness)

Alternative	Priority in availability and timeliness	Overall priority
A1. Three-stage recovery	0.4	0.065
A2. Two-stage recovery	0.6	0.097
Total	1.0	0.162

Finally, by adding the overall priority values of each alternative, the one that contributes most to the goal is found. The sample results are shown in Table 6.

Table 6.6. The final priority of each alternative

Criteria Alternative	C1	C2		C3	C4		C5	C6			C7	Total
		SC1	SC2		SC1	SC2		SC1	SC2	SC3		
A1. Three-stage recovery	0.065	0.023	0.017	0.063	0.028	0.012	0.115	0.095	0.051	0.063	0.011	0.543
A2. Two-stage recovery	0.097	0.072	0.031	0.035	0.014	0.009	0.044	0.037	0.038	0.039	0.042	0.457
Total	0.162	0.095	0.048	0.098	0.042	0.021	0.159	0.132	0.089	0.102	0.053	1.00
		0.143			0.063			0.323				

According to the total priority of each alternative in this example, the three-stage recovery has a higher priority than the two-stage recovery.

6.6 Validation

Focus groups facilitate dynamic discussions among participants, allowing researchers to explore and refine theoretical constructs based on collective insights. This method is particularly effective in realist evaluations, where focus groups help in developing and testing middle-range theories through iterative cycles of theory gleaning, refining, and consolidation (Manzano, 2022). The interactive nature of focus groups enables the identification of shared experiences and divergent views, contributing to a more nuanced understanding of the theoretical framework. Additionally, maintaining dependability and confirmability through systematic documentation and transparent analysis processes enhances the trustworthiness of the research (Tümen Akyıldız & Ahmed, 2021). Thus, focus group research serves as a robust method for validating and refining theoretical frameworks in qualitative research. Interviews allow for qualitative feedback that can highlight unforeseen challenges, suggest improvements, or confirm the model's alignment with practical decision-making processes. According to Silverman (2013) expert validation through interviews ensures that models are grounded in practical knowledge, enhancing their credibility. Moreover, it is emphasised that qualitative interviews have a significant role in refining theoretical frameworks to ensure they are sensitive to the specific contexts they address (Kurzahls, 2021).

This model was validated through two rounds of interviews and a focus group method with local experts in the industry. The interviewees were chosen from the senior experts of the National Disaster Management Organisation (NDMO) of Iran, the Housing Foundation of Iran, and the experts from an NGO working in post-disaster recovery. The reason for choosing the mentioned experts is that the first two are the main decision-making departments in post-disaster recovery and reconstruction in Iran, and the third one is one of the most experienced NGOs active in the aid and reconstruction operations. The focus group consisted of eight members, including five

participants from the NGO and three participants from the Housing Foundation of Iran. The target population and their codes are listed in Table 5.1.

Table 6.7. Focus groups and interviewees coding.

Experts	Codes	Survey type
NDMO Senior Experts	NDMO1-NDMO2	Semi-structured interviews
Housing Foundation Experts	HF1-HF3	Semi-structured interviews / Focus groups
NGO Experts	NGO1-NGO5	Semi-structured interviews / Focus groups

During the validation process, first, the interviewees expressed their opinions about the influencing parameters in the traditional decision-making processes and the details and requirements of a new model for supporting the decision-makers in this process. By thematic analysis of the interviews, five themes were identified from the interviews to assess and score the model based on. These themes are listed below:

- Ease of use
- Generalizability
- Credibility and reliability
- Customizability
- Additional considerations (scalability, stakeholder engagement, integration...)

In the second stage, the DSS model validity was discussed through the focus group method based on the above themes. The focus group participants discussed the most important requirements of a DSS, making it valid and practical to be used in the decision-making process and rated the model based on the themes. The final results are shown in the 6.8 Table.

Table 6.8. Focus group rating of the model across the five themes

Themes	Rating
Ease of use	7 out of 10
Generalisability	6 out of 10
Credibility and Reliability	8 out of 10
Customisability	9 out of 10
Additional considerations	7 out of 10

Following the validation process, the DSS model was revised based on the outcomes and was discussed in the second round of the interviews. On the theoretical ground, the model was validated and revised based on the qualitative methods using experts' opinions, and the practical performance of the model needs to be validated in future studies of parallel use, besides the current decision-making processes.

The combination of the three different departments in which the interviews and focus groups were done (mentioned in Table 6.7) shaped a reliable panel of experts with high levels of experience in assessing and validating the developed process.

6.7 Findings and Discussion

Examining the literature, we find that post-disaster decision-making processes are often complex and extensive, and a decision support system can assist decision-makers in this process. The AHP model proposed in this research requires a comprehensive survey of the available solutions in each housing scenario before any prioritisation and weighting, including the specification of the

technologies considered for use in emergency/temporary sheltering, temporary housing, alternative solutions, and permanent housing. These specifications encompass both qualitative and quantitative variables, and estimating the level of each variable requires parallel studies. It should be noted that, according to Lizarralde et al. (2010), the two-stage recovery model may also incorporate forms of temporary housing. Since the boundaries between temporary housing and facilitated winterised shelters or similar solutions are not clearly defined, the two- and three-stage recovery models specified in this study may share similarities and may not be significantly different. Nevertheless, they still need to be evaluated and compared with each other. The AHP method allows multiple decision-makers with different areas of expertise to assess the importance of criteria relevant to their specialisation and make pairwise comparisons. Additionally, multiple individuals can contribute to one comparison and consolidate their opinions using methods such as the Delphi method.

The qualitative data required for pairwise comparisons in this process may necessitate additional studies on displaced people's preferences and priorities. For example, determining the priority between staying in higher-quality temporary housing versus completing permanent homes sooner depends on prior social studies of displaced people's characteristics and demographics.

The main target users of this DSS include the post-disaster recovery decision-making committees in Iran which are basically consisted of the authorities of the Red Crescent managers, the Housing Foundation experts, the NDMO professionals and the local authorities of the affected area.

6.7.1 Research limitations:

The decision support system introduced in this research is only for specific cases in which deciding between using or not using the temporary houses is relevant and not for the post-disaster circumstances where using temporary houses is inevitable or is not possible. Also, successful decision-making in a post-disaster context depends on having extensive knowledge of the geographic and demographic attributes of the region and, according to Davis and Alexander (2015), the two and three-stage models used in this research reduce the complex sheltering and housing processes to simple titles that may oversimplify the diverse permutations in recovery processes. Therefore, it should be noted that the decision-making method developed in this research should be used in conjunction with other considerations specific to each unique case.

6.8 Conclusion and future research

Successful post-disaster recovery requires making timely and accurate decisions. These decisions should address the immediate needs of displaced people while also considering the long-term impacts. Deciding whether or not to use temporary housing in situations where this dilemma arises has been one of the controversial and significant issues following some recent disasters in Iran. This research developed an MCDM method to assist decision-makers in selecting the most suitable housing model between the two mentioned options. The process involves pairwise comparisons of the models using the AHP method based on six criteria extracted from the literature and interviews. The proposed process was validated and refined through qualitative data collected from Iranian experts in post-disaster reconstruction. Further research is needed to explore ways to improve decision-makers' accuracy and performance in assigning priorities during pairwise comparisons. Exploring the potential of artificial intelligence for this purpose may be a valuable approach.

Epilogue:

This chapter aimed to develop and validate a novel decision support system to support decision-makers in selecting the most appropriate post-disaster housing recovery model. This objective has been successfully achieved through the design and formulation of a structured framework grounded in the findings of the previous chapters, followed by its validation using relevant methods.

The developed system incorporates key decision-making parameters, including technical, social, environmental, and user-centered considerations, ensuring a comprehensive and context-sensitive approach. Its validation confirms the applicability and reliability of the proposed model in addressing the complexities of post-disaster housing decisions in Iran. By bridging the gap between empirical findings and practical implementation, this chapter provides a robust tool that contributes directly to improving the efficiency, responsiveness, and sustainability of post-disaster housing strategies.

7 Chapter 7: Discussion

7.1 Discussion

This research developed a comprehensive decision support system tailored for decision-making in post-disaster housing recovery, with a specific focus on the temporary housing stage. The study aimed to address key research objectives, which included extracting and classifying the requirements for post-disaster housing, analysing the latest technologies and their impacts on housing recovery, investigating processes and policies applied in recent post-disaster housing projects, and ultimately developing and validating a novel decision support system to support decision-making. Through critical literature reviews, case studies, qualitative exploration, and stakeholder interviews, the study achieved these objectives, providing a structured framework for navigating the complexities of temporary housing decisions.

The complexities of post-disaster decision-making underscore the need for systematic frameworks that account for the dual demands of immediate action and long-term sustainability requirements. Post-disaster recovery operates within a highly dynamic environment where decisions must balance the urgency of providing immediate relief with considerations of long-term social, economic, and environmental impacts (Davis & Alexander, 2015). Temporary housing, as an intermediate phase, often bridges this gap but poses significant challenges due to its transient nature, high costs, and implications for permanent recovery. This research highlights the critical importance of adopting structured and evidence-based decision-making tools to navigate these challenges effectively.

The Analytic Hierarchy Process, as a Multi-Criteria Decision-Making method, proved to be a reliable approach for addressing the complexities of temporary housing decisions. AHP's strength

lies in its ability to decompose complex problems into hierarchical structures, allowing decision-makers to evaluate multiple, often conflicting, criteria systematically. This capability is particularly valuable in post-disaster contexts, where factors such as cost, timeliness, cultural compatibility, and sustainability must be simultaneously considered. By enabling a comparative assessment of these factors through pairwise comparisons, AHP supports nuanced and transparent decision-making, making it well-suited for the intricate challenges of temporary housing. The integration of case studies and qualitative data into the DSS further enhanced its contextual relevance and practical applicability. Case studies provided empirical insights into past recovery efforts, highlighting both successful strategies and recurring challenges, while qualitative interviews with stakeholders offered critical perspectives on local needs, priorities, and constraints. This combination of methodologies ensured that the DSS was grounded in real-world experiences, making it adaptable to diverse disaster scenarios.

The findings of this research expand upon the existing literature regarding post-disaster housing reconstruction, which historically emphasizes the deep-seated challenges of balancing immediate relief with long-term rehabilitation goals (Lizarralde et al., 2010). Globally, extensive work has documented the recurrent systemic failures of temporary housing solutions, ranging from logistical bottlenecks and prohibitive costs to stark cultural and environmental incompatibilities within displaced populations. In response to these persistent issues, some international studies have evaluated the complete elimination of the intermediate temporary housing stage in favour of accelerated permanent construction programs (Fallahi & Binesh, 2009). However, as noted in previous academic examinations, such two-stage recovery frameworks frequently result in severe social and psychological distress when vulnerable groups are left exposed to harsh climatic conditions without adequate intermediate transitions.

What makes this research unique within the established literature is its contextual focus on the local disaster landscape of Iran and the subsequent development of a specialized framework to resolve these conflicting recovery strategies. While general disaster management studies focus on high-level policies or isolated structural models, local insights from Iranian recovery processes—spanning from the 1990 Gilan-Zanjan earthquake to the 2022 Hormozgan disaster—reveal that critical institutional knowledge remains heavily siloed and reliant on individual decision-makers. Past literature underscores severe regional shortcomings such as space shortages, cultural mismatches, and the eventual degradation of temporary settlements into urban slums. By systematically extracting these region-specific operational constraints and socio-cultural dynamics, this study bridges a major gap in localized knowledge that broader global frameworks consistently overlook.

Furthermore, the DSS developed in this research stands out as a novel and distinct mechanism in the field of MCDM for crisis response. Traditional algorithmic literature often utilizes optimization systems primarily focused on the allocation metrics of space and delivery logistics (El-Anwar et al., 2009). In contrast, the unique architecture of this developed DSS implements the AHP specifically to weight and resolve whether a two-stage or a three-stage housing recovery model is fundamentally appropriate for a given post-disaster scenario. By explicitly integrating expert stakeholder panels with local criteria such as climatic compatibility, long-term sustainability, and community preferences, the system offers an unprecedented tool that institutionalizes transient crisis management knowledge, successfully reducing the historical reliance on uncoded, individual-based decision-making panels.

The AHP model showed that any advancement in construction technologies affecting the speed, quality, or costs of the construction in temporary or permanent housing will affect the correct decision and can have great impacts. Moreover, using reusable or recyclable temporary houses can decrease their overall negative impacts. On the other hand, any weakness in providing the fundamental needs of the displaced people, such as providing a safe and resilient living space, will lead to the failure of the related alternative. Therefore, adopting a systematic decision-making approach not only enhances the quality of the outcomes but also provides decision-makers with a more comprehensive perspective, enabling them to analyse the problem from different angles while considering varying priority levels.

The research objectives were successfully achieved. The DSS was developed to prioritise critical criteria such as sustainability, cultural compatibility, and scalability alongside emergency response efficiency. The framework was validated through expert feedback, demonstrating its capacity to guide decision-makers in selecting appropriate temporary housing models. Additionally, the findings reinforced the importance of long-term considerations in temporary housing solutions. While the primary goal of temporary housing is to provide immediate shelter and stability, its design and implementation significantly influence the trajectory of permanent recovery. Poorly planned temporary housing can lead to prolonged displacement, increased costs, and environmental degradation, emphasising the necessity of adopting sustainable and context-sensitive approaches.

The lessons learned from this study can be summarised as follows:

Disasters should be prevented whenever possible, as they are not natural occurrences but rather the result of vulnerabilities in responding to natural phenomena such as earthquakes and floods. However, achieving fully resilient and future-proof societies remains a challenge, making new disasters inevitable. Countries prone to such events, like Iran, experience disasters annually.

Post-disaster temporary housing plays a crucial role in Iran's recovery process, significantly impacting the lives of those affected by recurrent earthquakes and floods. However, past disasters have revealed severe shortcomings in temporary housing systems. These issues range from inadequate funding, supply, and delivery to poor compatibility, sustainability, and long-term effectiveness.

Key weaknesses in Iran's temporary housing processes include delays in delivering temporary housing, inefficiencies in permanent housing construction, unsuitable locations and layouts, high energy consumption due to climatic incompatibility, space shortages, lack of privacy, and cultural mismatches. Additionally, temporary housing settlements have, in some cases, turned into slums over time, leading to further social and economic problems.

Due to these challenges, there has been a growing tendency to eliminate the temporary housing stage from post-disaster recovery efforts. Over the past two decades, studies have documented cases where decision-makers attempted to implement a two-stage recovery process, focusing on immediate sheltering followed directly by permanent housing. Various policies, including financial incentives and rapid construction techniques, have been used to encourage displaced people to seek rental housing or stay with host families, aiming to expedite permanent housing solutions.

While this approach has succeeded in some cases, it has failed in others, leading to severe social consequences. In successful cases, resources were concentrated on permanent housing, leading to faster reconstruction. However, in unsuccessful cases, the absence of temporary housing left vulnerable populations in tents during harsh weather conditions, causing significant physical and psychological distress. This led to widespread dissatisfaction and, in some cases, forced authorities to reverse their decisions, reintroducing temporary housing after significant delays, which resulted in increased costs and public discontent.

The decision-making process for post-disaster housing recovery typically begins after each disaster. A decision-making panel evaluates various factors, including the disaster's severity, the extent of destruction, seasonal and climatic conditions, geographical characteristics, accessibility, available funding, and social dynamics. However, past experiences indicate that this process has weaknesses and inefficiencies due to reliance on individual-based decision-making, the absence of a structured decision-making framework, and the urgency of post-disaster circumstances.

As a result, decisions can be biased and may not fully consider the essential factors required for an effective recovery strategy. To address this issue, this research develops a decision-support system for determining whether temporary housing should be included in post-disaster recovery. The framework utilizes the Analytical Hierarchy Process, a multi-criteria decision-making method suitable for complex problems.

The AHP method in this study is designed around key factors influencing post-disaster recovery. It incorporates the perspectives of a diverse panel of stakeholders, including local decision-makers and experienced experts. Through this process, the advantages and disadvantages of a two-stage versus a three-stage housing recovery model are compared, with results calculated using AHP software.

This decision-support system offers several advantages over traditional approaches. It provides a more comprehensive, multi-dimensional, and efficient method for evaluating recovery strategies. By integrating expert and local perspectives, the system ensures more inclusive decision-making. Additionally, it balances immediate emergency needs with long-term sustainability considerations. Another significant benefit is its potential to systematize crisis management knowledge in Iran, reducing reliance on the expertise of senior individuals and enabling the transfer of critical knowledge to future generations.

Several factors contribute to improving post-disaster housing recovery, and achieving recovery goals requires deploying all effective mechanisms and policies. The use of new technologies, such as rapid construction methods, and innovative design strategies, including core shelters and modular housing, can be transformative. However, to effectively integrate these technologies and strategies, decision-making must be systematic and evidence-based. A decision-support system facilitates faster and more reliable evaluations of alternative solutions.

The rapid development of artificial intelligence (AI) will further enhance the decision-making process by enabling more extensive and precise analysis of influencing factors. This advancement is expected to lead to faster, more efficient, and more informed recovery decisions in the future. Additionally, training and customising AI for each country or region will enhance the decision-making process.

8 Chapter 8: Conclusion

This research addressed the complex challenges of post-disaster housing recovery by developing a decision support system tailored to temporary housing in Iran. Through a systematic and multi-faceted approach, the study investigated the issues and priorities associated with temporary housing, leveraging Multi-Criteria Decision-Making principles to create a structured and adaptable framework. 9 research objectives were defined to guide the study, focusing on extracting and classifying housing requirements, analysing relevant technologies, understanding stakeholder needs, and proposing a validated DSS to support decision-making. These objectives were successfully achieved through a combination of critical literature reviews, case studies, qualitative explorations, and stakeholder interviews. The findings, published in five research papers, contribute to both theoretical and practical knowledge, offering insights for improving post-disaster housing decision-making.

The decision support system developed in this research demonstrates the potential of MCDM methods, particularly the Analytic Hierarchy Process, to enhance the quality, transparency, and sustainability of temporary housing solutions. By integrating diverse criteria such as cost, timeliness, sustainability, and cultural compatibility, the framework provides decision-makers with a comprehensive tool to evaluate housing alternatives and prioritise solutions that balance immediate relief with long-term recovery goals. The research also underscores the critical importance of adopting systematic approaches to decision-making in post-disaster contexts, enabling stakeholders to address the urgency of housing needs while considering broader socio-economic and environmental impacts. This study offers a robust foundation for improving temporary housing practices in disaster-prone regions and highlights opportunities for future

research, including testing the DSS in real-world scenarios and integrating emerging technologies to further enhance its capabilities.

Overall, this study contributes to the field of disaster recovery by proposing a structured and adaptable framework for temporary housing decision-making. The use of AHP within the DSS demonstrates the potential of MCDM methods to enhance the post-disaster decision-making processes. By bridging the gap between immediate recovery needs and long-term resilience goals, the findings of this research offer valuable guidance for policymakers, practitioners, and researchers working to improve housing recovery outcomes in disaster-affected communities.

8.1 Recommendations

8.1.1 Recommendations to decision-makers

The primary recommendation for decision-makers is to incorporate lessons learned from previous experiences to prevent the recurrence of past mistakes. In Iran, disaster management and reconstruction organisations employ experienced personnel who are responsible for making critical decisions on recovery and reconstruction methods based on their accumulated knowledge. However, it was revealed through the interviews that this expertise is currently heavily reliant on individuals, underscoring the need for systematic documentation and development to benefit future decision-makers. A systematic approach within decision-making systems can enhance this process by institutionalising these learned lessons and experiences. This approach can enhance the quality of decision-making processes and contribute to the sustainability of the organisation (Carayannis et al., 2014).

The development of the decision support system demonstrates that, in scenarios where both the use and non-use of temporary housing are viable options, the introduction of a new idea or

technology can shift priorities in pairwise comparisons, thereby altering the final decision. Consequently, it is essential to adopt a comprehensive approach that considers all potential settlement options and associated technologies.

8.1.2 Recommendations to Policymakers

When deciding on an appropriate post-disaster temporary housing model, policymakers must consider both the immediate needs of affected populations and the long-term impacts on community recovery. It is crucial to prioritise models that ensure rapid deployment, adaptability to local contexts, and resilience against future environmental threats. Studies have shown that modular housing solutions can offer significant advantages in terms of cost-effectiveness, ease of transport, and flexibility in adapting to diverse geographic and cultural settings (Félix et al., 2013; Johnson et al., 2006). Additionally, incorporating sustainable building materials and designs that align with the local climate can enhance comfort and reduce environmental impact. Policymakers should also create pathways to engage with affected communities and understand their preferences and needs, as resident satisfaction is a critical determinant of the housing model's success in fostering social cohesion and supporting mental well-being during the recovery phase (Ganapati & Ganapati, 2009). By considering these factors, decision-makers can make informed choices that not only address immediate shelter needs but also contribute to resilient and sustainable post-disaster recovery efforts.

8.2 Research limitations

All of the data in this research was collected from Iran, and therefore, the applications will be limited to Iran's post-disaster recovery context. Consequently, the research findings may have limited applicability for generalisation. However, the decision support method and related

knowledge can be helpful in similar post-disaster decision-making problems in other countries with similar problems.

There were several limitations in the data collection process. Firstly, site visits and face-to-face interviews were impossible during the COVID-19 pandemic. As a result, all the interviews with displaced people and most of the interviews with experts were done after that period. Secondly, in the data collection of the case study, the diversity of male and female participants among the interviewees was limited because of cultural specifications. Also, the data collection sample size was limited to the number of displaced people who consented to participate in the interviews. Thirdly, the validation of the developed decision support system was based on the industry experts in post-disaster reconstruction with high levels of experience in the field; however, the limitations in their scope and interpretations should be considered.

Implementation challenges represent another key limitation. Given the diverse array of decision-makers involved in post-disaster recovery and Iran's ongoing political instability, deploying the developed decision support system in real-world contexts will be complex and require sustained stakeholder engagement. Successfully translating these findings into practice will necessitate identifying effective dissemination channels and clearly communicating the system's value to relevant authorities. Because such knowledge transfer and the cultivation of future collaborations are inherently time- and resource-intensive, they constitute a significant limitation of this research.

8.3 Future research

Future research should focus on testing the developed decision support framework in real-world post-disaster scenarios to evaluate its practical applicability, effectiveness, and adaptability. This could involve deploying the framework in diverse disaster contexts, encompassing varying scales, geographic locations, and socio-economic conditions, to assess its capacity to accommodate

complex, context-specific factors. Field studies could provide valuable insights into how decision-makers interact with the framework, highlighting its usability and areas for improvement. Incorporating feedback from stakeholders, including government agencies, humanitarian organisations, and affected communities, would be instrumental in refining the framework's functionality and ensuring its alignment with on-the-ground realities. Additionally, comparative analyses of outcomes achieved through the framework versus conventional decision-making methods could offer empirical evidence of its impact on improving cost efficiency, timeliness, and sustainability in temporary housing deployment. These investigations would not only validate the framework's utility but also pave the way for its broader adoption in disaster recovery practices.

Future research should also explore emerging technologies like 3D printing, modular construction, and advanced materials to create scalable, adaptable, and cost-effective post-disaster housing that aligns with local climatic and cultural needs. Emphasis should be placed on environmentally sustainable materials, such as recycled and biodegradable components, to enhance long-term sustainability. Enhancing Multi-Criteria Decision-Making (MCDM) frameworks with real-time analytics and AI-driven systems could improve decision-making and adaptability across diverse contexts. Cost optimisation efforts should evaluate hybrid systems, automated construction techniques, and public-private partnership models to enhance affordability. Community-centred approaches should include participatory decision-making models and tools like virtual reality for co-designing housing solutions. Timeliness in deployment could benefit from pre-positioned modular inventories, blockchain-optimised supply chains, and just-in-time manufacturing. Sustainability research should focus on net-zero housing models, lifecycle analyses, and circular economy principles. Strategic advancements in policy and management, including harmonised

guidelines, disaster-resilient housing standards, and stakeholder training programs, are essential for improving temporary housing outcomes globally.

9 References

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Appendix 1

This appendix includes the survey questionnaire.

Hormozgan province 2022 earthquakes _ Displaced people

This interview is designed to ask people's opinion about social sustainability indexes of post-disaster temporary houses used in the aftermath of Kermanshah earthquake:

Consent to Participate

Please read the following statements carefully before signing below to confirm your participation.

- **Voluntary Participation:** I agree to participate in this project of my own free will. I understand that my involvement is completely voluntary and that I can withdraw my consent at any time within four weeks from today.
- **Information & Questions:** I have read the provided Information Sheet. I have had the opportunity to ask questions about the study and know I can reach out to the researcher with further inquiries at any time.
- **Confidentiality:** I understand that my data will remain confidential and that my identity will not be disclosed in any research publications unless I explicitly give permission.

Signature: _____ **Date:** _____

Contact Information For any questions or concerns, please contact:

Alireza Shamloo, PhD Candidate, School of Built Environment, Massey University
Email: A.shamloo@massey.ac.nz

Please answer these questions about the social sustainability indexes of post disaster temporary houses used after Kermanshah earthquake.

Demographic Information

Gender

☐ Female ☐ Male

Age

☐ Under 18 ☐ 18 to 24 ☐ 25 to 34 ☐ 35 to 44 ☐ 45 to 54 ☐ 55 to 64 ☐ 65 or older

Housing Experience

1. Assistance Type

Question: Did you receive a temporary housing unit or the equivalent cash assistance?

- ☐ Temporary housing unit (prefab, cabin, container, etc.)
- ☐ Equivalent money/cash assistance
- ☐ Both a housing unit and financial assistance
- ☐ Neither

2. Wait Time

Question: How long did it take for you to receive your temporary housing unit or financial assistance after the disaster?

- ☐ Less than 2 weeks
- ☐ 2 weeks to 1 month
- ☐ 1 to 3 months
- ☐ More than 3 months

3. Duration of Residence

Question: How long have you been living (or did you live) in your temporary house/shelter?

- ☐ Less than 1 month
- ☐ 1 to 6 months
- ☐ 6 months to 1 year

- ☐ 1 to 2 years
- ☐ More than 2 years

4. Perception of Safety

Question: How safe did you feel living in your temporary house?

- ☐ Very safe
- ☐ Safe
- ☐ Neutral
- ☐ Unsafe
- ☐ Very unsafe

5. Structural & Weather Resilience

Question: Do you feel your temporary house/shelter was sufficiently resistant to subsequent earthquakes and harsh weather conditions?

- ☐ Highly resistant
- ☐ Somewhat resistant
- ☐ Neutral
- ☐ Not very resistant
- ☐ Not resistant at all (highly vulnerable)

6. Indoor Comfort

Question: How comfortable was your temporary house in terms of living space, thermal comfort (temperature control), and acoustics (noise levels)?

- ☐ Very comfortable
- ☐ Comfortable
- ☐ Neutral
- ☐ Uncomfortable
- ☐ Very uncomfortable

7. Privacy Satisfaction

Question: How satisfied were you with the level of privacy your temporary house provided?

- ☐ Very satisfied
- ☐ Satisfied
- ☐ Neutral
- ☐ Dissatisfied
- ☐ Very dissatisfied

8. Compatibility with Personal Needs

Question: How well did the temporary house accommodate your specific family or personal needs (e.g., size, accessibility, cultural habits)?

- ☐ Completely compatible
- ☐ Mostly compatible
- ☐ Neutral
- ☐ Mostly incompatible
- ☐ Completely incompatible

9. Recovery Trade-off Preference

Question: In a similar disaster recovery scenario, which option would you prefer?

- ☐ Living in a high-quality temporary house for a longer period
- ☐ Moving into a permanent house as quickly as possible, even if it means enduring a lower-quality temporary shelter in the short term
- ☐ No preference / Undecided

10. Location Satisfaction

Question: How satisfied were you with the location of your temporary house (e.g., proximity to your original neighbourhood, jobs, schools, and healthcare)?

- ☐ Very satisfied
- ☐ Satisfied
- ☐ Neutral

☐ Dissatisfied

☐ Very dissatisfied

11. Core Challenges

Question: What were the biggest problems you faced while living in the temporary house or shelter? *(Select all that apply)*

☐ Extreme indoor temperatures (too hot or too cold)

☐ Lack of physical space/overcrowding

☐ Lack of privacy from neighbours or within the family

☐ Poor safety, security, or lock issues

☐ Poor location (too far from work, schools, markets, or social networks)

☐ Inadequate utility access (water, electricity, sewage, internet)

☐ High cost of living/maintenance

☐ Psychological stress or feeling unsettled

☐ Other (Please specify): _____

Appendix 2

This appendix includes the analysis of the focus group discussions on validating the DSS.

Validity of the DSS Based on Thematic Analysis

Theme 1: Ease of Use

- **Explanation:** This theme revolves around the usability and accessibility of the DSS (Decision Support System) for various users, including local authorities, NGOs, and non-experts. Experts noted the intuitive structure of the decision tree but expressed concerns regarding the complexity of the AHP (Analytic Hierarchy Process) method, the need for training, and the time-consuming nature of pairwise comparisons, particularly during post-disaster chaos. Suggestions included a simpler user interface, pre-weighted models, and user guides.
- **Evidence:** NGO1, HF1, NGO2, HF2, and NGO3 discussed the learning curve, the need for training, and the possibility of having a simplified mode or guidance to increase efficiency.
- **Score:** 7/10
- **Justification:** This score reflects a moderate level of ease of use, as the DSS has a clear structure but requires significant support (such as training and guides) to be effective for a diverse range of users, especially in emergencies.

Theme 2: Generalizability

- **Explanation:** This theme focuses on the ability of the DSS to adapt to different types of disasters (e.g., earthquakes, floods) and the diverse geographical and cultural regional

contexts of Iran. Experts pointed out the flexibility of AHP in weighting criteria but emphasized the need for customization to address regional differences, such as cultural variations or disaster-specific priorities (e.g., seismic resilience).

- **Evidence:** HF3, NGO4, NGO5, and HF1 discussed applicability across various scenarios, the need for modular design, regional case studies, and the inclusion of context-specific criteria.
- **Score:** 6/10
- **Justification:** This score indicates fair generalizability due to the flexibility of AHP, but the lack of built-in regional adaptability partially limits its effectiveness across Iran's diverse landscapes.

Theme 3: Credibility

- **Explanation:** This theme addresses the trustworthiness and reliability of the DSS, which is linked to the established reputation of the AHP method, the quality of input data, the transparency of the decision-making process, and the comprehensiveness of the criteria. Concerns were raised regarding data accessibility, potential biases, and the absence of a governance criterion.
- **Evidence:** NGO2, HF2, NGO3, and NGO1 referred to the credibility of the method, the need for data validation, transparent reporting, and addressing bias or coordination challenges.
- **Score:** 8/10

- **Justification:** The high score reflects strong credibility due to the recognition of AHP and the comprehensive criteria, though concerns about data quality and stakeholder alignment temper it.

Theme 4: Customizability

- **Explanation:** This theme explores the adaptability of the DSS to specific needs, such as adding or removing criteria, adjusting sub-criteria based on cultural contexts, or customizing outputs (e.g., hybrid models). Experts recognized the potential flexibility of AHP weighting but called for more dynamic features, such as editable decision trees or community-specific sub-criteria.
- **Evidence:** HF3, NGO4, NGO5, and HF1 discussed the need for modular design, cultural adaptation, and flexible outputs to respond to local and situational needs.
- **Score:** 9/10
- **Justification:** This score indicates a high level of customizability. While the current system allows for weight adjustments, it lacks robust tools for structural modifications or diverse output options. *(Note: The original Persian text states "indicates moderate customizability" despite giving a high score of 9/10).*

Theme 5: Additional Considerations (Scalability, Stakeholder Involvement, Evaluation, Integration)

- **Explanation:** This theme encompasses broader concerns, including the scalability of the DSS for large-scale disasters, the importance of community involvement, the need for ongoing evaluation to adapt to changing needs, and integration with tools like GIS or cost estimation software. These aspects were viewed as critical for practical implementation.

- **Evidence:** NGO2, HF2, NGO1, and NGO3 mentioned managing multiple regions, community input, feedback loops, and tool integration to enhance functionality.
- **Score:** 7/10
- **Justification:** This score reflects significant potential and importance, as these considerations target practical deployment challenges, though they require further development to be fully realized.

Summary of Themes and Scores

Ease of Use: 7/10 – Intuitive, but requires support for diverse users.

Generalizability: 6/10 – Flexible, but requires regional customization.

Credibility: 8/10 – Strong foundation with some data and process concerns.

Customizability: 9/10 – High potential with room for structural improvement.

Additional Considerations: 7/10 – Critical for implementation but incomplete.

These scores and themes provide a balanced evaluation, highlighting the strengths of the DSS (e.g., credibility, generalizability) while identifying areas for improvement (e.g., ease of use, customizability) to enhance its effectiveness within the context of post-disaster housing reconstruction in Iran.