Sustainability in the Post-Disaster Temporary Housing Management for Urban Areas

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Abstract

Many people lose their homes every year due to natural disasters. One of the major challenges to mollify displaced persons is the provision of adequate post-disaster accommodations, temporary housing (TH) being the most common alternative. While the need for TH is dramatically increasing, this is criticized from a sustainability standpoint. Contrarily, a universal approach to temporary housing cannot successfully deal with this issue because each recovery has singular conditions.

In this context, temporary housing units (THUs) have been used to serve as an alternative residence while the permanent housing process is being completed. This model has been widely used in previous recovery programs even though several drawbacks have been reported. Nonetheless, the lack of potential of certain areas persuades decision-makers to implement THUs. In view of this contradictory panorama, it is evident that decision-makers need to be supported in selecting adequate type of THUs to reduce the negative impacts of TH when there is no other possibility.

To this end, this research presents a novel approach to determine sustainable solutions for TH in terms of economic, environmental and social requirements while integrating the stakeholders' preferences and the local conditions. This has been calibrated and validated with 5 study cases: (1) earthquakes in Turkey (1999), (2) Iran (2003), (3) Italy (2009), (4) and tsunami in Indonesia (2004), and (5) hurricane and flood in USA (2005).

The proposed approach results in four new models: (1) a conceptual model oriented to assess the sustainability of post-disaster temporary housing alternatives; (2) a model to support decision-makers in discriminating the optimal site location of temporary housing; (3) a model to determine potential area subsets that meet certain area requirements to settle the THUs; and (4) a model for choosing optimized THUs. These models are directly based on the sustainability concept integrating the three main accepted pillars (economic, environmental and social).

It should be emphasized that the MIVES method has been used throughout the research to deal with the sustainability assessment. This method permits minimizing the subjectivity in the decision-making process and relies on the value function concept.

This new general approach is meant and designed to be a decisive support for decision-making in the field of TH management.

Chapter 1

Introduction

1.1. Introduction

There exist clear evidences that global climate change is modifying the characteristics of natural hazards such as intensity, timing, frequency, and types (Field 2012). **Natural disasters** are caused by a complex combination of natural hazards and disastrous human actions (Blaikie et al. 2014). These have affected two hundred and eighteen million people each year on average between 1994 and 2013 (The Centre for Research on the Epidemiology of Disasters (CRED) 2015). This implies that since the turn of the

millennium, more than one million of people died and other 2.3 billion have been directly affected by natural disasters around the world (Guha-Sapir & Santos 2013). Furthermore, according to UNHCR (2015), the total displaced population reached almost sixty million by 2014, eight million more than previous years. Meanwhile, in 2050, the population of areas highly prone to natural disasters is expected to double the values of 2009 (Lall & Deichmann 2009).On the other hand, **people affected** by a natural disaster have the right to live with dignity and to receive assistance to alleviate human suffering (Sphere project 2004). People who have lost their home because of disaster or conflict need somewhere to live while the permanent houses are being build, or find alternative accommodation (Corsellis & Vitale 2008). In this regard, it should be mentioned that sustainable reconstruction often takes and years, especially in urban environments (Transitional Shelter guideline 2012). It is always a challenge the provision of shelter for **displaced people (DP)** during this period time. Sphere project (2004) states provision temporary settlement after disaster is necessary for supplying security and personal safety, protection from the climate and immunize people from disease. It is also important for human dignity and to sustain family and community life as far as possible in effortful conditions (Félix et al. 2013; Joseph et al. 2008; Sphere Project 2004).

During permanent housing construction processes DP need to have access to safe accommodations. The authorities could officially provide **temporary housing** (TH) as most previous recovery programs did, such as homes of relatives, rental accommodation, temporary housing unit (THU), shipping container, etc. If those authorities in charge of providing TH conceals this process completely or these are slow in erecting temporary settlement, DP provide shelters for themselves as TH (e.g., the Colombian recovery program after the Armenia earthquake, 1999 (Johnson et al. 2006)).

Temporary housing (TH), which can start few weeks after the disaster and be finished in a couple of years, is applied to provide secure and safe conditions (Collins et al. 2010; Davis 1978). TH is considerably criticized in terms of the stakeholders' satisfaction. In general, according to (Aysan & Davis 1993; Barakat 2003; Chandler 2007; Coffey & Trigunarsyah 2012; El-Anwar et al. 2009; Hadafi & Fallahi 2010; Johnson 2002; Wei et al. 2012), the problems of TH can be categorized into: economic, social, and environmental aspects; in other words, the **sustainability** concept. The unsuitable outcomes of most previous recovery programs reported by the researchers have been: (1) long delivery time, (2) cultural contradictions, (3) large public expenditures, (4) consumption of investment and resources assigned to permanent buildings, (5) delay on permanent building delivery,

(6) inappropriate second life, (7) environmental pollution, (9) change of strategy several times, and (10) top-down approaches.

Besides, it should be emphasized that as diverse areas with different prosperity and living standards require **individual strategies** (Building Regulations 2010; Johnson 2007a), a response to different natural affected-areas should be provided resorting to customizable approaches (Kennedy et al. 2008). In this regard, Nigg et al. (2006) stated that the PDA typology is not particular or collectively comprehensive; the refinement of typology of these accommodations is mandatory to achieve suitable customized solutions. Meanwhile, shortfalls in the existing platforms established for the analysis of previous recovery programs' outcomes and for providing future strategies lead to multiply difficulties of decision-making process. Therefore, considering prior cases' results to determine the particular factors of a previous case, which can lead to the special outcomes for each case.

1.1.1. Decision-making process for temporary housing

The connection between a chosen strategy and its outcomes is usually missed link and this should be determined to achieve a customizable model. The link of this process includes many diverse factors, such as local potentials, natural disasters type and intensity, DP characteristics, climate conditions, life standards, political issues, and so on. On other hand, most researchers indicated the importance of pre-planning for recovery program. Consequently, in order to provide a suitable strategy for next natural disasters a model for analysing varied factors of possible alternatives should be provided. In this regard, although researches have analysed post-disaster recovery programs, there are few studies proposing flexible models to deal with this issue. In general, dealing with this issue, including influencing factors with even antithetical impacts on each case making, is a complicated challenge for decision-makers. Additionally, some factors of PDA can completely be in conflict, such as proximity to pre-disaster private properties and protecting DP form future hazards. Besides, the existing knowledge for assessing the exact disaster level is still far from sufficient (Blaikie et al. 2014).

Additionally, taking into account the numerous influential factors of TH, it is required to guarantee the contribution of a wide range of experts and stakeholders in TH process in order to achieve appropriate solutions. This fact could cause difficulties in the decision-making process and human errors. In this regard, Lizarralde & Davidson (2006) stated that strategies provided by a non-representative group of professionals, often fail in addressing the DP expectations.

This situation confirms that providing TH for DP in a short time and usually in great number is complicated in terms of satisfying all beneficiaries' needs, regardless of the societies' welfare levels. Furthermore, when previously used strategies are applied to different areas, the chosen strategies are most likely destined to fail, unless the strategies are context and culturally based.

1.1.2. Rural and urban areas

Especial attention should be paid to the differences between recovery programs in **rural and urban areas** since these present quite diverse situations (Comerio 1997). In this sense, TH program of an urban area and a rural area can be the same based on local characteristics similarities of these two. According to International Federation of Red Cross and Red Crescent Societies (2010), urban areas should be assessed individually due to the diverse characteristics, homes and other buildings, population concentrations, transportation infrastructure and industries that these present. Although, urban areas have more potential to deal with natural disasters, these areas could be vulnerable because of other factors, such as high density. The urban population is expected to reach the 66% of the world population by 2050 (UN 2014). Thus, the importance of the suitability of TH strategies has increased due to the expected increasing in the urban population in the next years as well as the increase of population living in areas with natural hazard risk.

1.1.3. Temporary housing units

Temporary housing units (THUs) strategy, which is one of most used TH strategies, has been refused by most researchers. According to (Johnson 2009), THUs often have been provided with prefabricated technology after natural disasters. This type of TH is required to be constructed usually after natural disasters. Therefore, a THU can be defined as a building provided by third parties for short-term usage by DP, and is entirely distinct from permanent housing. THUs are often categorized as a camp (United Nations High Commissioner for Refugees (UNHCR) 1999), grouped in planned camps (Corsellis &

Vitale 2005), organized in a top-down approach (Johnson 2007a). However, THUs can be erected on private properties or on camp sites.

According to Félix et al. (2013), THUs consist in: (1) ready-made units and (2) supply kits. Although a THU is often conceived as a precast system (Johnson 2009), on-site masonry construction was used in previous TH programs. As most types of THU are constructed after disasters in a short period of time and in large quantities, THUs do not meet usually beneficiaries' needs. Indeed, the most mentioned **problems of TH** are related to this strategy; nevertheless, this has not been technically analysed with the aim of decreasing negative impacts.

TH should be guided with the principles of predictability, effectiveness, timeliness, responsibility and accountability (Joseph et al. 2008); although, even following these principles, post-disaster THUs solutions still present some problems. THUs have been criticized for their incapability to meet the expectations of DP (Chen 2012). This criticism stems from various reasons, including:

- The TH late delivery (Bolin 1993; Friday 1999; Johnson 2007).
- Failure to fulfil the social, psychological, and economic needs of displaced families (Bolin 1982; Bolin and Bolton 1986; Comerio 1998; Friday 1999; Golec 1983; Johnson 2007a; Marcillia & Ohno 2012; Tomioka 1997).
- Poor TH locations (Bolin 1993; Chen 2012; El-Anwar et al. 2009a; Kelly 2010; World Bank 2010).
- High cost of TH process (Davis & Lambert 2002; El-Anwar et al. 2009b; Félix 2013; Friday 1999; Johnson 2002, 2007a; World Bank 2010).
- Negative impact on environment (Arslan 2007; Arsalan & Cosgun 2007; Chandler 2007; Félix et al. 2013)
- Shortage optimization and *analysing* models (El-Anwar et al. 2009a; Chen 2012).

Although, there is a big difference between THUs and other types of TH (rental units and core housing strategies) in terms of the mentioned issues, TH with low negative impact is not always applicable. This occurs because of the unavailability of units, DP´s resistance to displacement, shortfall in participations, and so on. Moreover, other factors, such as climate conditions, could force decision-makers to use THUs. As an example, the Turkish government decided to provide a large amount of THUs aftermath of the earthquake in

1999 because 180,000-240,000 people were living in tents and tight rental market while winter was coming (Johnson 2007a). On other hand, DP of metropolitans cannot be expected to participate to provide TH due to shortfalls in motivations, free time and required skills.

In general, researchers stated to avoid using THUs because the negative impacts associated with this technology. Meanwhile, analysis of previous recovery programs concluded that THUs has been applied in the vast majority of situations. This confirms that there is still no suitable alternatives for replacing THUs. Therefore, this must be accepted and assessed in order to determine in detail the related problems in order to minimize negative effects. To this end, although **negative impacts of THUs** should not be disregarded, the disadvantages of these units should be mitigated to obtain more sustainable solutions. The present research is oriented to assess the negative impacts of THUs from the technical point of view by categorizing the problem into site location and units' technology.

According to (El-Anwar et al. 2009a; Johnson 2002, 2007a; Johnson et al. 2006; Lizarralde et al. 2009), finding an appropriate **site location** that could minimize the delay of the units' delivery, DP´s dissatisfactions, expensive processes and environmental pollution is a problem of THUs. Inadequate site selection for THUs could cause even more negative economic impacts if THUs are rejected due to unsuitable site location, such as the Bam, Iran, and Pescomaggiore, Italy, cases (Fois & Forino 2014; Ghafory-Ashtiany & Hosseini 2008). In this concern, site selection embraces several steps from planning to construction: (1) initial inventory; (2) alternative analysis; (3) assessment; (4) detailed design and (5) construction procedures and services (Kelly 2010).

Another problem of THUs is selecting **units' technology** without considering local requirements. Johnson (2007a) stated that THUs' materials should be adjusted to guarantee a second life. Sometimes THUs are refused by the DP due to lack of knowledge of new technologies. For instance, lightweight blocks system, a technology that requires less mortar and speeds up construction compared to bricks, was no longer applied in the Aceh recovery program due to local cultural preferences (Da Silva 2010). Additionally, inattention to other TH properties, such as durability for a second life, often coerces decision-makers to change the initial strategy. As an example, in the Aceh case, although tents were cheap and easily prepared, those could not stand out against the tropical climate conditions. In contrast, the high-quality buildings of the L'Aquila program led to extend the shelter phase. On the other hand, according to Johnson (2007a), high-quality TH could be a reason to make it difficult for DP to move to permanent housing. However, this is completely related to DP characteristics, and example is how the high-quality THUs of Pescomaggiore and New Orleans did not attract the DP (Fois & Forino2014; McCarthy et al. 2006).

Indeed, choosing between high-quality TH and short period of TH usage uses to be a dilemma. According to Tafti, and Tomlinson (2013), there was a specific case in which the owner was living about eight years after the disaster in Bam TH until 2011. In this regard, the Turkish government forced the users of THUs, tenants and new migrants, to leave by cutting off the services THUs of the Turkey housing program in 2005, while the earthquakes happened in 1999 (Johnson 2007b). Thus, it is necessary to assign use time of THUs by considering DP characteristics, second life and quality of units. If there is an explicit long-term plan for recovery program based on adjustment of THUs to local conditions and potential, this problem could be solved. In order to **achieve** this goal it is required to consider problems of THUs with accuracy. Furthermore, not only individual mentioned factors should be considered, but also the integration of these factors must be guaranteed in order to sustainable outcomes.

1.2. Motivation

In general, based on aforementioned information, the problems that will appear in futures in most urban areas, such as Tehran, are including: increase of urban population; land scarcity; land price; elevate several times of expenses incurred by disaster in metropolitan area compared to rural area; changing natural disasters; change in ratio residences to residents; enhance slums around large cities.

Additionally, it should be emphesized that natural hazards cannot be eliminated. Meanwhile, the characteristics of future natural hazards, as intensity, timing, frequency, types, change due to the global climate change in addition to increase of urban areas vulnerability (Field 2012). At the end, especial attention should be paid to THUs, which have general negative impacts of the building industry for short time usage under emergency conditions. Hence, the building industries experts are required to involve in this issue to **decrease negative impacts**, beside emergency managers and other specialists. While, THUs have been used for most previous recovery programs.

Beyond all universal mentioned aims, some metropolitans, such as Tehran, capital of Iran, with high density and other risky characterises need to be considered with accuracy in order to be prepared for probabilistic natural hazards. Meanwhile, Tehran is located on seismic areas with several faults, as shown in Fig. 1.1. Moreover, consideration of historical background of earthquakes demonstrates that high possibility of occurring an grate magnitude earthquake (Ghodrati Amiri et al. 2013). According to the Japan International Cooperation Agency (JICA) and Centre for Earthquake and Environmental Studies of Tehran (CEST) study (2000), if a probabilistic earthquake occurs during the day, it will cause almost 18,000 casualties, more than 610,000 DP, and 90,000 damaged residential buildings in total. Therefore, it is highly necessary to enable the decision-makers for dealing with difficult problem aftermath of probabilistic earthquake.

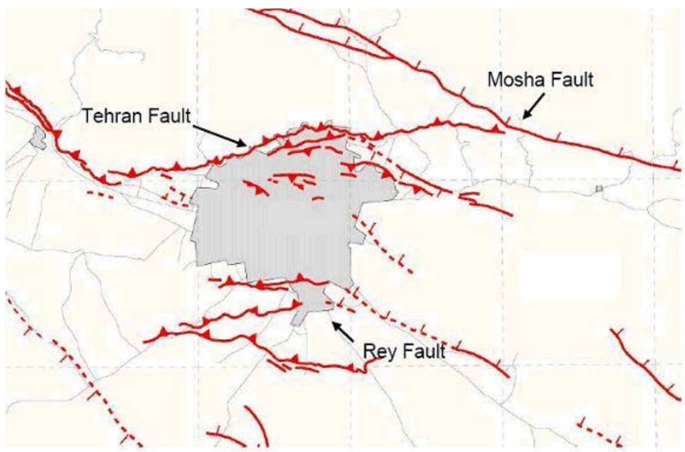

Fig. 1.1. Map of Tehran´s faults

1.3. Objectives

The **main objective** of this research is to **propose a platform for decision-makers for dealing with temporary** housing **in natural hazard-prone urban areas**. This platform should be flexible and adaptable to the local conditions of each area while guaranteeing sustainable solutions and considering the stakeholders'' preferences.

To this end, the following specific **objectives were** established:

(1) To propose a model for **choosing the most suitable temporary housing strategy**. This TH strategy should be capable of bringing higher beneficiaries' satisfactions by considering individual local conditions.

(2) To develop a model for **selecting an optimized location** for THUs based on sustainability concepts.

(3) To establish a model for assisting decision-makers in selecting **the most sustainable area subsets** from various alternatives to implement the TH strategy.

(4) To design a model for selecting **the most optimal THU alternative in terms of sustainability** by considering the different preferences of the involved stakeholders.

1.4. Methodology and Thesis arrangement

This study is generally organized into two main parts: Descriptive and Operational, as shown in Fig. 1.2. The Descriptive section embraces the problems, requirements, limitations, potential responses, chosen strategies, and their outcomes. This section is broken down into two parts; first part takes into account TH issues and second part considers definition of other related issues to the objective as sustainability and decision process. The Operational section presents operational models to achieve defined specific objectives by designing models, applying for case studies, and analysing.

In the Descriptive section, definition and organization of TH characteristics and requirements in terms of technical aspects are carried out by simplified categories in (**chapter 3**).

In this regard, diverse types of TH are considered in order to determine a customizable strategy. Consequently, the characteristics of TH are identified in the three categories: *time-scale*, *housing style*, *second life*. In (**chapter 3**), which is conducted based on analysing case studies and problems, assesses the five case studies: Marmara and Duzce earthquakes, 1999; Bam earthquake, 2003; Aceh earthquake and tsunami, 2004; Katrina Hurricane, 2005; and L'Aquila earthquake, 2009. The TH strategies of cases are studied in order to detect strengths and weaknesses of the strategies and defined factors that results demonstrate almost all cases struggled with TH. In (**chapter 4**), which takes into account the definition of sustainability of TH, requirements of TH sustainability assessment are defined. To this end, this study assessed definition of TH sustainability by previous researches, moreover, presents a new structure of TH sustainability, including general frame, necessities, existent limitations and **impediments** to achieve this purpose, and sustainable TH. (**Chapter 5**) considers TH decisions area, including characteristics, conditions, and requirements, for dealing with TH, and suitability of decision-making models, especially multi-criteria decision-making methods based on having demanded and defined factors.

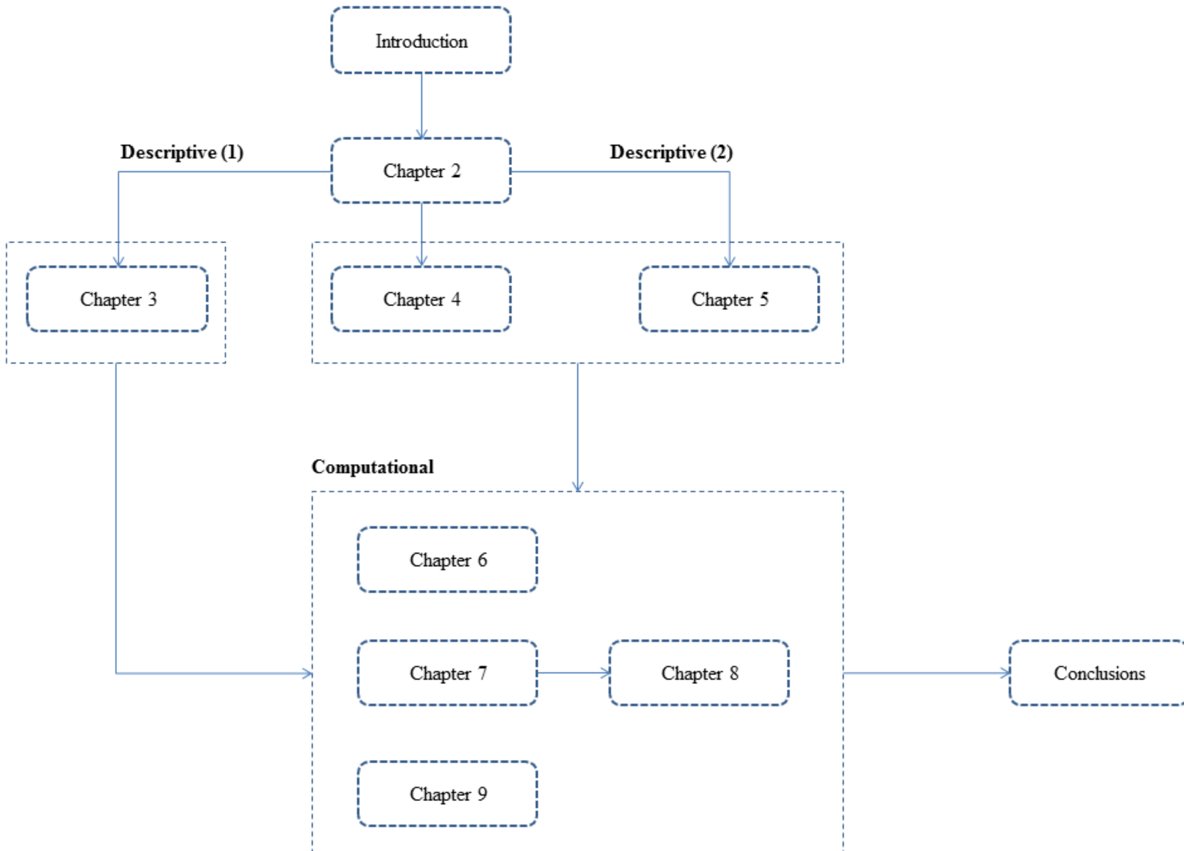

Fig. 1.2. Organization of doctoral thesis

In the Operational section, four models are designed in order to enable decision-makers to deal with multifaceted TH issue by decreasing human errors. Thus, the first model takes into account sustainability of TH generally with regard to all possible alternatives, such as THUs, mobile homes, rental units, etc. The next third models aim to consider sustainability of main vertexes of THUs, as location and unit suitability

In this regard, (**chapter 6**) takes into account to choose types and location of TH in general among all possible alternatives based on steps scenarios to avoid increasing negatives impacts. Indeed, this model creates an opportunity for decision-makers to determine a more appropriate strategy in order to minimize the conflict between local requirements and TH characteristics by considering all beneficiaries' satisfactions. (**Chapter 7**) designs a new model to select a most suitable site location of TH among possible alternatives in urban areas based on the Integrated Value Model for Sustainability Assessment (MIVES). The model is capable of discriminating the optimal site location based on the integration of economic, social, and environmental aspects into the whole life cycle of these houses. For the application example, a total of six different alternatives for temporary housing are assessed, which include 23 different sites in Tehran. Additionally, in (**chapter 8**), a model is provided to select a sustainability subset, includes diverse alternative sites, whose total areas are equal specific demanded area. Meanwhile, possibility of selecting huge amount of subsets among acceptable/available alternative sites could be very complicated and time consuming to arrive at the sustainable solutions by considering all stakeholders' satisfactions. This model is conducted based on MIVES and Knapsack algorithm. Additionally, like the first section **(chapter 7)**, site location for TH in the case of a probabilistic earthquake of Mosha's fault in Tehran, Iran is considered. (**Chapter 9**) designs a new model to consider sustainability of THUs by using MIVES. In this case, a total of four different THUs, ACC, CMU, PR, and 3D technologies, from the Bam earthquake in 2003 are assessed to test the designed model and analyse the THUs used.

Finally, (**chapter 10**) considers the specific and general conclusions of all chapters and future perspective, which is required to be assessed in future researches. Furthermore, it should be emphasized that study of multifaceted TH issue with intertwined factors is required to be considered based on diverse points of view. To this end, this research contains different separate sections, which are formed as unique articles. However, the unity in diversity concept is established for this research.

Additionally, this research aims to provide a unique process to determine and choose sustainability results from beginning phase until second life of TH. Nonetheless, there are many remained areas (aspects), which must be considered by future researches. Future researches most likely struggle with less problems and current limitations. In this regard, a main limitation is shortfalls in explicit technical information that leads to assess problems from begging to end by researchers separately. This fact causes to waste many times to derive and collect information. Additionally, sometimes it is very difficult to obtain accurate data from local authorities, primary sources. Meanwhile, increase trends of publications in this area could assist to future research to achieve reliable information and comparable models.

Chapter 2

State-of-the-Art

2.1. Introduction

This part of the thesis studies and analyses the literature review related to the object of study. It does this by defining and applying a general strategy and a specific strategy that are described in the following subsections. Then it analyses the main research projects from the main researchers and finally a brief analysis is carried out to draw some conclusions.

2.2. Research Background

In order to deal with multifaceted sustainability issues of Temporary Housing (TH), which include diverse factors, this research organizes the problem into three categories: (1) TH generic factors (see methodology), (2) sustainability aspects, and (3) decision-making models. This literature review is also organized in these three categories. Regarding to the first category, there are relevant studies about definitions of TH elements that are considered in this chapter. To this end, the main factors of TH with regard to previous researches are presented in this section. The second and third categories are assessed in **(chapters 4 and 5**) of this thesis. Additionally, some researches, which embrace diverse intended aspects of this study, are mentioned in several chapters.

As a general conclusion, it should be emphasized that many studies have conducted descriptive research focusing on TH and related factors. On the other hand, few studies focus on the sustainability and optimization of TH.

2.3. General strategy

The general strategy used in this thesis to analyse relevant previous studies is presented in Fig. 2.1. As shown in Fig. 2.1 relevant studies are assessed to define requirements for the object of study and deficiencies, and low-considered aspects in the literature review. In this sense, the main factors of TH are classified in four groups: local conditions, TH characteristics, stakeholders' requirements, and natural hazards. Nevertheless, this Literature review section is based on the organization of previous researches in the TH areas with regard to considered topics, as shown in Fig. 2.1. Simultaneously, other factors of TH are clarified in the other part of thesis such as site selection factors in the related sections. To this end, previous studies have been assessed in order to extract necessary information with regard to most mentioned factors.

2.4. Specific strategy

Additionally, this literature review section applies another strategy to achieve suitable information from previous case studies as primary sources.. As shown in Fig. 2.2, this strategy consists in organizing the information of each case in three sections: input, processing and outcomes.

The *Input* section embraces (1) disaster, which includes hazard types and intensity, range of damages and casualties, and social resiliency; (2) population takes into account the affected and non-affected people of the area, which faces a natural disaster, and (3) strategy, which is chosen for dealing with a natural disaster by decision-makers.

The *Processing* section is the main object of this literature review and includes the elements that lead to the final results. These elements are: factors, priority of each factor and interconnections.

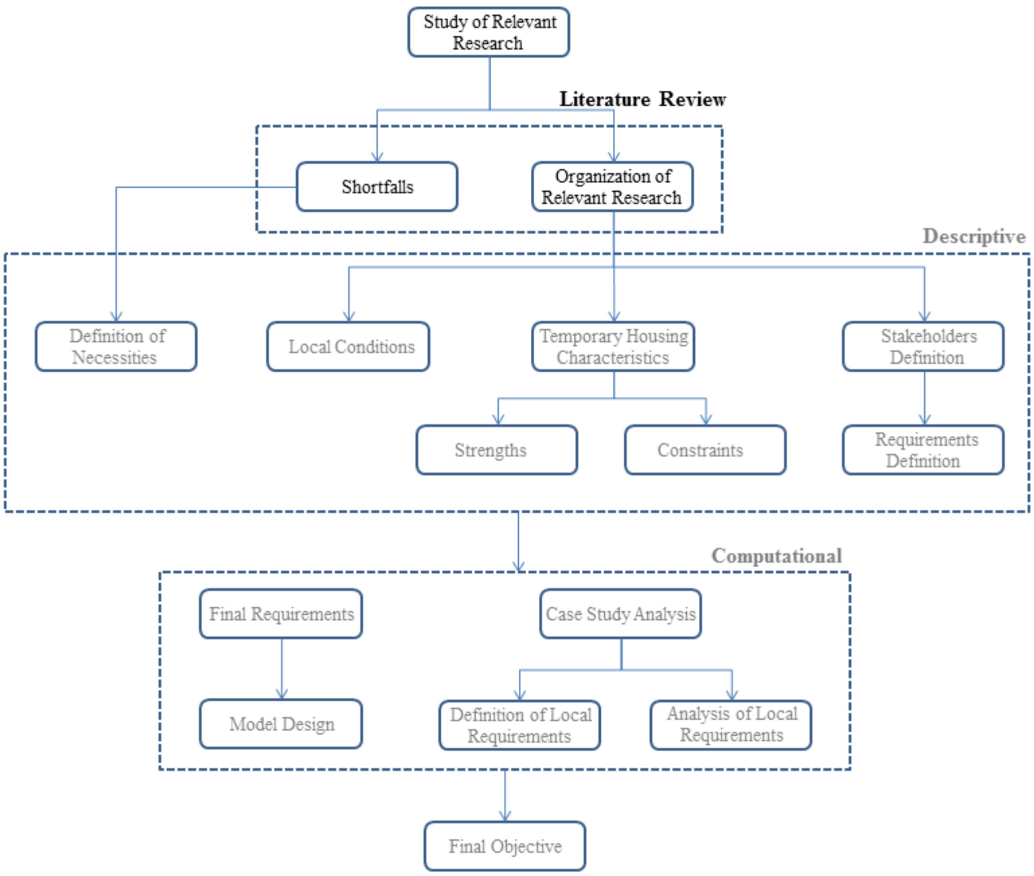

Fig. 2.1. General strategy for the literature review

The *Outcome* section, takes into account the satisfaction range of people who are involved in the TH process. This study organizes these people in three groups: users, producers, and third-party. Users need assistance and a place for residing due to the natural disaster. Producers such as authorities, investors, engineers, workers, etc., are involved in providing suitable accommodations and conditions for the affected population to return to the pre-disaster conditions. Third-party are all the other people that are involved in post-disaster recovery programs (except the first and second groups). For instance, NGOs for supportive environment, host of DP and neighbours are categorized in the third-party group.

2.5. Specific strategy for case studies

In general, this study aims to realize the elements of the *Processing* section for the five case studies defined in **chapter 3**. This has the purpose to discover potential results by applying another alternative strategy for the same case or using the same strategy for another case, as shown in Fig. 2.2. This is accomplished by analysing the five cases and deriving influential factors. Consequently, the factors are arranged into explicit vertexes for the simplification of this decision-making process.

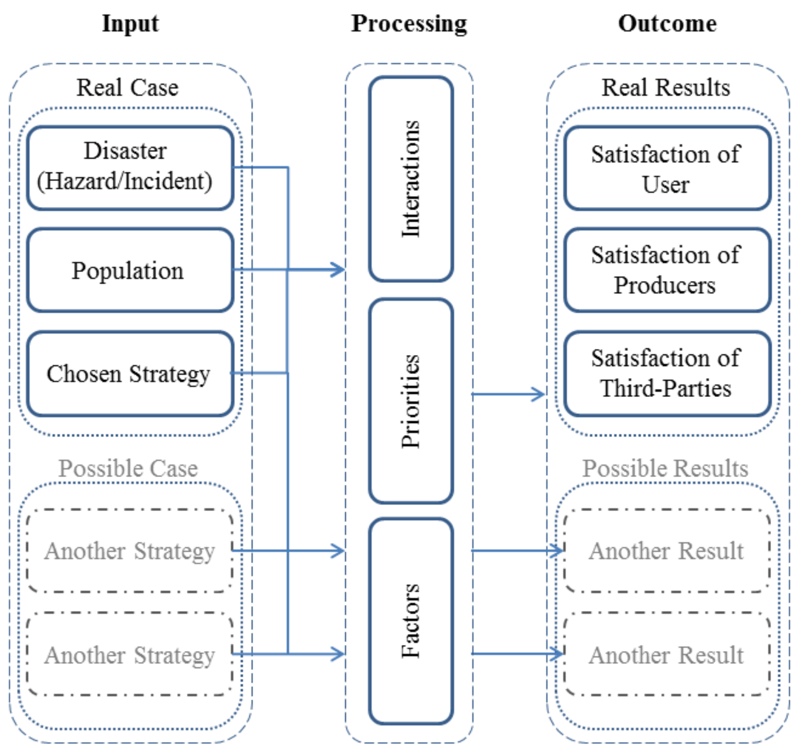

Fig. 2.2. Methodology for considering the PDA process including input, processing, and outcome

2.6. Research projects analysis

The most relevant researchers and research groups have been assessed in terms of the most mentioned TH factors in their research projects . Table 2.1 presents the results in order to analyse them. A special attention should be paid to two points: (1) the presented factors in Table 1 could contain diverse sub-indicators but this chapter only aims to consider and to organize previous studies based on the general aspects; (2) this chapter exclusively considers the most (a limited number of) cited researches and guidelines while numerous studies in this area have been not considered.

2.7. Summary Definition of References

David E. Alexander (1 in Table 2.1) has published many studies in different aspects of disaster risk based on disaster management and response planning. This author carried out researches about L'Aquila post-disaster housing policy.

Beyond Range (Protracted Refugee Camps) (2 in Table 2.1) has been prepared by Daniel Sundlin, Karl Johan Nyqvist in 2010 that assesses history of camp and shelter. Additionally, this defines organizations and NGO that are involved to sheltering issue and the responsibilities for refugees. Moreover, this analyzes last made camps. Indeed, this research is as a handbook for emergencies in terms of shelter indicators by evaluating real erected camps as a sample.

Beyond Shelter: Architecture and Human Dignity (3 in Table 2.1) considers twenty–five reports about prevention and recovery programs aftermath of natural disasters, such as Indonesia tsunami 2004, Solomon island earthquake 2007, Pakistan earthquake 2005, New Orleans hurricane 2005 and etc. This presents post-disaster construction approaches that has been done to learn disaster architecture from past disaster response. This book, which has been provided by Marie J. Aquilino in 2011, asks question about the role and responsibility of architects in disaster recovery.

Chandler Philip J. (4 in Table 2.1) has accomplished master thesis "Environmental Factors Influencing the Siting of Temporary Housing in Orleans Parish" in 2007. This dissertation considers TH response to Hurricane Katrina in Orleans parish during the five months immediately following the disaster declaration, specifically, the environmental factors and socioeconomic factors of the temporary housing sites.

Lei Chen (5 in Table 2.1) has considered quantitative methods to incorporate the displaced families in terms of socioeconomic in 2012. This research focuses on optimization model to find adequate temporary settlement such as rental houses, public building and etc. Indeed, this model only illustrates Web-based system according to relevant studies that are involved in TH. In this dissertation Pareto model has been used as a multi-objective optimization module.

Table 2.1. The parameters that are taken from bibliography references

No.	Parameters / Research Projects	Economic	User Safety	Climatic	Vegetation	Neighbourhood	Danger	Case study	Hazards	Definition	Long-term shelter	Urban and Rural	Design	Material	Construction	Maintenance	Demolition	Satiation	Site selection	Emission	Recourse	Evaluation	Technical Detail	Management
1	**Alexander, 2004, 2010, 2011**			x				x	x		x	x			x									x
2	**Beyond Range, 2010**		x		x			x		x									x					
3	**Beyond Shelter , 2011**	x	x	x			x	x		x	x		x	x										
4	**Chandler, 2007**		x																x	x		x		
5	**Chen, 2012**	x					x	x				x	x						x					
6	**Chu and Su, 2012**		x									x	x						x					
7	**Deployable emergency, 2008**		x									x	x	x	x					x				x
8	**Engineering in emergency, 2002**		x		x		x						x	x	x				x	x			x	
9	**El-Anwar et al. 2009, 2010**	x	x				x					x			x				x	x	x	x		
10	**Handbook for emergencies, 2000**		x	x	x	x	x			x			x		x				x		x			x
11	**Housing issue, 1997**							x											x					
12	**Housing reconstruction, 2003**	x	x				x				x		x	x	x				x					
13	**How to Build, 2008**		x					x					x	x									x	
14	**Humanitarian Charter, 2004**		x		x								x						x					
15	**Johnson, 2002, 2007**	x	x	x		x				x	x	x		x	x	x	x		x	x			x	x
16	**Kelly, 2010**		x	x		x	x			x								x	x					x
17	**Quarantelli, 1993, 1995**		x							x														x
18	**Rehabilitation,*1993***		x	x			x			x		x												x
19	**Safer Homes, 2010**	x	x											x	x									x
20	**Shelter after disaster, 2010**			x						x			x											
21	**Shelter after disaster, 1982**		x	x			x		x	x	x				x				x					x
22	**Shelter project, 2008**							x						x	x									x
23	**Transitional settlement, 2005**		x	x						x			x	x	x	x			x			x	x	x
24	**Transitional settlement, 2008**		x				x						x					x	x					x
25	**Transitional Shelter, 2009**		x	x						x	x			x		x								x
26	**Transitional Shelter, 2009**		x								x		x	x	x									
27	**Transitional shelters, 2011**		x					x			x		x	x	x								x	

Jianyu Chu, Youpo Su (6 in Table 2.1) have studied in 2012 based on the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method for selecting fixed seismic shelters. This research presents an evaluation system, which contains three first-level indexes and nine second-level indicators related to essential factors such as risk of hazard, location & size and rescue facilities. The weights of indicators are considered by use of AHP and entropy methods.

Deployable Emergency System (Arquitecturas Desechables de Emergencia) (7 in Table 2.1) has been provided by Andrea Balducci Caste, Ana Cocho Bermejo, and Daode LI. in 2008. This presents new model emergency building that has a minimum effect on environment. Additionally, this model, which are good ideas for ergonomics post-disaster architecture was organized, based on flexibility architecture in anywhere and anytime.

El-Anwar (8 in Table 2.1) has a many research about TH after disaster based on optimization model. This researcher has created a new model to find a significant alternative for displaced people based on maximize distance from danger sources that called user safety and minimize public expenditures according to Pareto Model. However, these researches do not embrace all influenced factors in life cycle of temporary housing especially environment requirements and other part of social requirements except distance to danger resource.

Engineering in Emergency: A Practical Guide for Relief Workers (9 in Table 1) has been prepared by Jan Davis and Robert Lambert in 2002. This book tries to increase the effectiveness of relief workers that participate in humanitarian assistance during an emergency. In order to this goal, the book provides practical information concern to the worker failed, with a minimum of supporting theoretical background.

This study presents a model to support decision-makers to find out adequate location site for refugee meanwhile, this model is more useful for rural area. The technical criteria have been defined as following: legal issues, potential for growing food, access, environmental health, fuel-wood availability, security, water sources, robust environment, flora and fauna, topography, natural hazard safety. The researchers suggested assigning the weights of criteria by considering team judgments based on percentages. Then the team should visit alternatives sites to determine parameters (points) of each criterion for each site between zero and one hundred. In the next step, the value of each criterion achieves by multiplying a parameter by a weight of each criterion. Finally, the total of criteria´s values presents value of each site.

Handbook for Emergencies (10 in Table 2.1) has been prepared United Nations High Commissioner for Refugees (UNHCR) in 2000. This handbook includes user safety, water supply, size of camp sites, land use and land rights, security and protection, topography, drainage and soil conditions, accessibility, climatic conditions and local health and other risks, vegetation, and site selection methodology. This manuscript considers rural area more than urban areas. The handbook presents adequate information such as size of camp, 30 m2 surface area per person includes the area necessary for roads, foot paths, educational facilities, sanitation, security, firebreaks, administration, water storage, distribution, markets, relief item storage and distribution and, of course, plots for shelter. if small vegetable gardens attached to the family plot should be included in the site plan from the outset, a minimum increase of 15 m2 per person, hence, a minimum of 45 m2 overall land allocation per person would be needed. In general, this provides some standards for campsite and TH.

Housing issue after disaster (11 in Table 2.1) has been written by Mary C. Comerio in 1997. This study considers natural disasters in the United States. Additionally, this compared the housing losses due to these with those happed in other places such as Iran, Mexico and Japan, etc.

Housing reconstruction after conflict and disaster (12 in Table 2.1) has been provided by Sultan Barakat in 2003. This study considers reconstruction aftermath of disasters. This offers how deal with post-disaster reconstruction by presenting diverse approaches and available challenges. The assessment of a wide range of examples concludes that it is required to consider local potentials, requirements, expectations, and constraints.

How to Build Safer Shelter (13 in Table 2.1) has been prepared by UN Habitat for International Federation of Red Cross and Red Crescent Societies in 2008.This carefully illustrated guide to how to build a safe shelter addresses cyclone-resistant construction. The basic principles of anchoring, bracing, and continuity for simple construction are illustrated. The importance of safe site selection and orientation and building shape are explained. Additionally, this makes safe bamboo construction accessible to the general public, as well as providing guidance for construction workers.

Humanitarian Charter and Minimum Standards (14 in Table 2.1)has been prepared by the Sphere Project in 2004. The project was launched in 1997 to develop a set of universal minimum standards in core areas of humanitarian assistance. The Sphere handbook is designed for use in disaster response, and may also be useful in disaster preparedness and humanitarian advocacy. This is designed to be used in both slow- and rapid-onset situations, in both rural and urban environments, in developing and developed countries, anywhere in the world. This offers a set of minimum standards and key indicators that inform different aspects of humanitarian action, from initial assessment through to coordination and advocacy. In addition, this considers minimum standards in hygiene promotion, water supply, excreta disposal, vector control, solid waste management, and drainage.

Cassidy Johnson (15 in Table 2.1) has published many studies in disasters and housing. This researcher has prepared adequate information about last happened earthquake in world and especially in Turkey. Johnson tried to make explicit definitions of factors are involved in TH based technical and organizational aspects.

Charles Kelly (16 in Table 2.1) has prepared the Green Recovery and Reconstruction in 2010. The Green Recovery and Reconstruction is training program designed to increase awareness and knowledge of environmentally sustainable disaster recovery and reconstruction approaches. Toolkit (GRRT) is dedicated to the resilient spirit of people around the world who are recovering from disasters. Additionally, this researcher presented a wide range of factors of site selection.

Enrico L. Quarantelli (17 in Table 2.1) has published many researches in natural disasters, especially in organizational aspects. This researcher presented suitable organization and definition in this area in order to clarify appropriate terms. Additionally, this author provides adequate strategies to deal with this issue, beside social aspects of post-disaster housing. Furthermore, this researcher provided explicit framework for researcher in this area based on requirements, limitations, weaknesses, and future researches.

Rehabilitation and Reconstruction (18 in Table 2.1) book has been written by Yasemin Aysan and Ian Davis in 1993. This book illustrates the key principles and strategies for effective rehabilitation and reconstruction after a disaster. This highlights the constraints and opportunities provided by these stages of recovery from the impact of damaging events.

Safer Homes, Stronger Communities *(*19 in Table 2.1) has been prepared by World Bank in 2010 that is a handbook for Reconstructing after Disasters. This is developed to assist policy makers and project managers engaged in large-scale post-disaster reconstruction programs make decisions about how to reconstruct housing and communities after natural disasters. As the handbook demonstrates, post-disaster reconstruction begins with a series of decisions that must be made almost immediately.

Shelter After Disaster (20 in Table 2.1) are the revision of the key publication Shelter After Disaster: Guidelines for assistance, published in 1982 by the office of the United Nation Disaster Relief Coordinators (now United Nation / office for the coordination humanitarian affairs.) The revision was drafted and reviewed over the period 2007-2010 at the Shelter Meetings, a biannual forum organized by Shelter Centre which is attended by the key NGO, IO, UN and government stakeholders. This guideline offers to governments, coordinators and implementer a platform for integrated shelter, settlement and reconstruction aftermath of natural disasters. This framework is intended to be consistent with government structures and humanitarian coordination mechanisms, supporting in both developing and implementing a single strategy, policy or plan for each response.

Shelter after disaster: Guidelines for assistance (21 in Table 2.1) has been provided by United Nations (UN) in 1982. This assesses the issue of shelter from the point of view of the survivor. This study provides guidelines on emergency shelter and post-disaster housing. This guideline considers almost all who are involved in post-disaster housing, such as governments, non-governmental, voluntary, etc.

Shelter Project (22 in Table 2.1) has been developed by the Emergency Shelter Cluster through under leading UN-HABITAT in 2008. This includes summaries of a range of experiences applied in crisis situations, and an honest appraisal of the successes and failures. This embraces many case studies, are specific based on individual contexts and the outcomes.

Transitional settlement: Displaced Populations (23 in Table 2.1) has been provided by Tom Corsellis and Antonella Vitale. First published by Oxfam GB in association with University of Cambridge shelterproject in 2005. The authors declare this book is published for coordinators and specialists working in humanitarian relief who are concerned with the transitional settlement needs of displaced people and their hosts. The guideline provides a common planning tool for developing and implementing settlement and shelter strategies for people affected by conflict or natural disaster. The guideline is divided into two sections: part a gives a broad overview of the issues relating to transitional settlement, and the six settlement options.

Transitional Settlement and Reconstruction after Natural Disaster (24 in Table 2.1) has been prepared by UN in 2008. This guideline is the revision of the Shelter after Disaster: Guidelines for Assistance, published in 1982 by UNDRO (now UN/OCHA). The guidelines cover coordination and strategic planning and implementation relevant to transitional settlement and reconstruction following all natural disasters. This covers the transition following a natural disaster from the emergency shelter needed for survival to durable solutions for communities, including identifying needs for support to communal infrastructure such as roads and hospitals, often over a period of several years.

Transitional Shelter Guideline (25 in Table 2.1) has been provided by International Organization for Migration (IOM). This was drafted and reviewed over the period May 2009–November 2011 at the Shelter Meetings, a biannual forum organized by Shelter Centre which is attended by the key NGO, IO, UN and government stakeholders in the global sector. This guideline includes definition and explains the ten principles of transitional shelter; indicate when a transitional shelter approach may be inappropriate; and provide guidance on how to design and implement a transitional shelter program.

Transitional Shelter Prototypes (26 in Table 2.1) has been prepared in 2009 by shelter center that meet the Transitional Shelter Standards, including only examples of stockpiled, airlifted family transitional shelters. This study presents a compilation of concept Transitional Shelter Prototype designs submitted by manufacturers working within Transitional Shelter Standards.

Transitional Shelters Eight Designs (27 in Table 2.1) has been published by International Federation of Red Cross and Red Crescent Societies in 2011. This presents the definition for transitional shelter as a product, as well as findings from the analysis and evaluation of eight implemented transitional shelter designs is using the following construction materials as following: timber, steel, and bamboo.

2.8. Conclusions of the literature review

From the aforementioned analysis about the literature review, it is concluded:

- User safety is mentioned more than the other parameters. Site selection is another significant parameter that has a high consideration in literature review.
- Some parameters have no or little consideration such as neighbourhood, demolition, maintenance, resource consumption and emissions.
- The number of studies about rural areas is higher than those about urban areas.
- The number of research projects focusing on disaster management is higher than those about technical assessment.
- There are no studies about the optimization of models for temporary housing assessment.

In general, technical parameters have been not or little considered in post-disaster housing research projects. Moreover, there is no or little optimization model in post-disaster housing. One of the first studies that consider evaluation of indicators in the post-disaster housing issues is the aforementioned study by **Jan Davis and Robert Lambert in 2002,** research 9 in Table 2.1.

Chapter 3

Integrated Approach for Dealing with Post-Disaster Housing

3.1. Introduction

Natural disasters, which are due to a complex combination of natural hazards and disastrous human actions (Blaikie et al. 2014), have affected two hundred and eighteen million people per each year on average between 1994 and 2013 (The Centre for Research on the Epidemiology of Disasters (CRED) 2015). Furthermore, according to UNHCR (2015), the total displaced population (DP) reached almost sixty million by 2014, eight million more than previous years. This increasing trend will continue due to population growth in cities prone to natural disasters and enhancing conflicts around the world.

People affected by a natural disaster have the right to live with dignity and to receive assistance to alleviate human suffering (Humanitarian Charter and Minimum Standards in Disaster Response 2004). In general, to recover natural-affected population there are three different recovery phases: (1) emergency, (2) temporary, and (3) permanent accommodation (Lizarralde et al. 2009). During the reconstruction of permanent housing, it is a challenge to provide temporary accommodation that can supply security and personal safety, as well as offer protection from the adverse weather conditions, immunize people of diseases, and other possible dangers (Collins et al. 2010; Davis 1978; Félix et al. 2013). Additionally, to bridge the time gap between natural disaster and permanent housing reconstruction, the DP need a place which enhance their opportunity to return to their normal activities (Davidson et al. 2006; Corsellis & Vitale 2005; Quarantelli 1995).

Furthermore, the provision of temporary housing (TH) is a crucial issue in terms of sustainability due to the economic, social, and environmental aspects involved (Barakat, 2003; Chandler, 2007; El-Anwar, El-Rayes, & Elnashai, 2009; Hadafi & Fallahi, 2010; Johnson, 2002; Sadiqi, Coffey, & Trigunarsyah, 2012; Wei et al., 2012). TH planning has usually been accomplished in emergency situations after natural disasters (Johnson 2002). The large amount of TH needs and DP pressure on authorities have a considerable negative impact on the decision-making processes. In general, recovery programs end into failure, when decision-makers neglect to consider correspondences between short- and long-term requirements of all local stakeholders and the characteristics of the chosen TH. Furthermore, strategies, which are provided by a restrained group of professionals, often fail to address the DP expectations (Lizarralde & Davidson 2006). To deal with this objective problem it is necessary to consider a wide range of factors involved, which derive from TH systems and actors beyond this system (Johnson 2007a).

These mentioned problems can be lessened by considering all factors involved in the whole life cycle of TH with regard to special conditions of each case and context. As different areas with diverse local living standards and prosperity require particular strategies (Johnson, 2007a ; United Nations Disaster Relief Organization (UNDRO) 1982), a response to different natural affected-areas need to have an individual approach (Kennedy et al. 2008). In this regard, Nigg et al. (2006) stated that the post-disaster accommodation (PDA) typology is not particular or collectively comprehensive; the refinement of typology of these accommodations is required to achieve suitable customized solutions. Additionally, Da Silva (2010) declared that the most adequate programs should be chosen based on: the DP skills and capacity, the availability of the local materials, the housing design and construction type, the reconstruction timescale and the funding availability.

Therefore, it is necessary to consider all factors in terms of fitting with different situations and priorities of stakeholders, including some factors of less importance than others. For instance, site location, which seems to have lower priorities than timing, has a considerable impact on TH delivery time (Johnson 2002) as one of the major indicators. Furthermore, the importance of indicators can vary from case to case based on natural disasters types and scales. To this end, awareness about outcomes of used PDA in previous recovery programs with the particular circumstances is vital to utilize some PDA approaches for a new case. In line with this, it is difficult to guarantee that the PDA program which has been useful for one case will be suitable for another case with different conditions. In other words, the determination of factors involved in each PDA provision and revealing outcomes, can provide explicit initial outlines.

Therefore, the **objective** of this research is to present a platform for decision-makers in hazard-prone areas for selecting the suitable PDA strategy to implement, based on short-term and long-term requirements. This platform considers the integration of all associated factors which are organized into three main vertexes: (1) local characteristics, (2) natural disasters, and (3) PDA properties. Additionally, this study aims to display influences of these elements on choosing strategies, which were previously used for PDA provision. In this sense, the main three questions to be solved in this research are:

- Which are the main requirements involved in PDA strategies and the constituents?
- Which are the differences between implemented PDA strategies?
- What are the social and physical outcomes of applying each PDA strategy? (When/Where/How can each strategy of PDA provision be applied?)

3.2. Methodology

This research has been conducted in three parts: first, a definition of the three vertexes and the associated components is presented. These components have been derived from primary and secondary sources, and arranges these factors in the three main groups (local characteristics, natural disaster, and PDA properties), as shown in Fig. 3.1. Second, five cases are presented and assessed to ascertain each case strategy and its benefits with regard to the three main vertexes: (1) earthquakes in Turkey (1999), (2) Iran (2003), (3) Italy (2009), (4) earthquake and tsunami in Indonesia (2004), and (5) hurricane and flood in USA (2005). Finally, a customizable strategy, which includes choice phases and the decision-making process algorithm, for dealing with PDA is proposed.

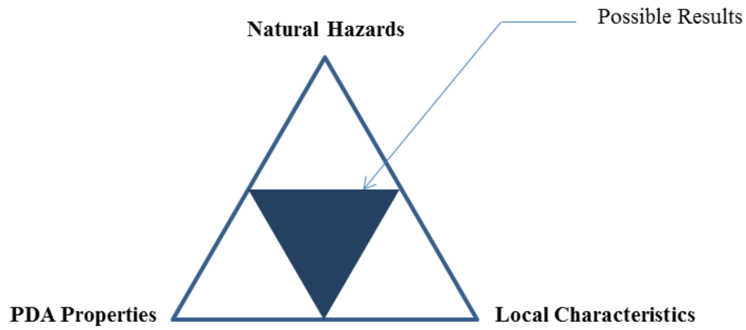

Fig. 3.1. Three main vertexes of PDA

Additionally, this research focus on TH, which is a part of PDA; though the post-disaster phases in terms of accommodation provision sometimes cannot be separated from each other due to approaches. To this end, the term PDA is used for diverse temporary accommodation types, referring to the accommodation where DP reside after the natural disaster to permanent housing. This study also focuses on *technical* systems more than *organizational* systems of recovery program based on definition of two systems developed by Johnson et al. (2006). However, in this case it is not possible to separate these two systems completely or to focus on one of these two independently.

3.3. Research Background

Numerous significant research studies have focused on defining the issues related to TH, especially organizational system. However, only a few studies consider TH optimization (El-Anwar et al. 2009), sustainable construction (Yi & Yang 2014), and technical aspects. Additionally, to provide a proper PDA it is necessary to distinguish between two different areas of recovery programs (*organizational* and *technical* systems). To this end, other researches that deal with issues and aspects (provision, location, and second life) also considered in this research have been previously carried out (see Table 3.1).

Table 3.1. Previous studies on post-disaster accommodations based on considered issues by this study

Issue	Sub-issue	Research
State-of-the-art	Definition	Abulnour, 2014; Barakat, 2003; Davis, 1978; Félix, Branco, & Feio, 2013; Félix et al., 2015; Hadafi & Fallahi, 2010; Johnson, 2009; Peacock, Dash, & Zhang, 2007
Technical	Provision	Barakat, 2003; Chen L. , 2012; Davidson et al., 2007; Hosseini, de la Fuentea, & Pons, 2016a; Johnson, 2002, 2007 b; Johnson, Lizarralde, & Davidson, 2006
	Location	Lizarralde & Davidson, 2001 Chandler, 2007; Chen et al., 2013; Chua & Su, 2012; Hosseini, de la Fuentea, & Pons, 2016b; Kelly, 2010; Nojavan & Omidvar, 2013; Omidvar, Baradaran-Shoraka, & Nojavan, 2013; Soltani et al., 2014
	Second life	Arslan, 2007; Arslan & Cosgun, 2007, 2008; Johnson, 1995, 2007a

3.4. Post-disaster housing

3.4.1. Post-disaster housing phases

According to (Johnson et al. 2006; Quarantelli 1995), the post-disaster housing phases are in general as follow: (1) emergency shelter (within hours), (2) temporary shelter (within days), (3) temporary housing (TH) (within weeks), and (4) permanent (within years). Additionally, UNDRO (1982) considered three phases for post-disaster recovery program: (1) intermediate relief (impact to day 5), (2) rehabilitation (day 5 to 3 months), and (3) reconstruction (3 month onward).

UNDRO (1982) stated DP need to be protected against adverse weather conditions and need access to healthy water and food during the first hours after a disaster takes place. In this stage, which is equivalent to the defined emergency shelter stage by Quarantelli, usually a public building, which is called *collective centre* by Corsellis and Vitale (2008), is used for settling DP. According to (Johnson 2007 a; Johnson et al. 2006), shelters are provided for DP to use from the first days post-disaster to the next few weeks such as tents or plastic sheets by Red Cross/Red Crescent, with help of the army as a temporary shelter. According to (Asefi, and Sirus 2012; Félix et al. 2015), the temporary shelter, which can be organized into transformable and non-transformable elements, needs to be available quickly. Indeed, basic needs of life including immediate shelter, food, water, etc. are provided for DP in these two stages with minimum privacy areas. Sometimes DP have small private areas for resting and collecting the things such as the paper partition system designed by Japanese architectures Shigeru Ban's. Meanwhile, some areas, such as sanitary services, communication area, dining hall, etc. are public.

The TH phase can start a few weeks after the disaster and be finished in a couple of years after the disaster. In this stage, the DP can return to normal life activities (Collins et al. 2010; Johnson, 2007a), such as providing food, work, etc. similar to the situation before the natural disaster by living in temporary accommodations, such as hotels, temporary housing units (THU), mobile homes, containers, etc. Finally, the last stage is permanent housing, in which the DP are in charge of all aspects, such as food providing, building maintenance, etc., with a better quality of life and more responsibility compared to the TH phase.

3.4.2. Temporary housing provision approach

To bridge the time gap between the emergency phase and permanent housing the TH phase is required despite the fact that the investment in TH has been questioned by most experts (Johnson 2009). However, this stage is unavoidable and cannot be concealed because DP need somewhere to live during the permanent housing construction process. Therefore, each residential option, which is used by DP for this time, can be called TH. For instance the recovery program of L'Aquila, Italy, 2009, seems to conceal the TH process with winterized tents, as the temporary shelter; and semi-/permanent housing played a TH role during the housing reconstruction phase. Furthermore, if who is in charge of providing TH conceals this process completely or is slow in erecting temporary settlement, DP provide shelters for themselves as TH such as, the Colombian recovery program after the Armenia earthquake, 1999 (Johnson et al. 2006).

In general, post-disaster recovery programs in terms of TH provision can be organized into (1) *separate (individual) stages* and (2) *joint stages*, as show in Fig. 3.2. In the first approach, a specific accommodation is used for each recovery phase encompassing the emergency, temporary, and permanent housing phases. However, some materials of these houses can be reused for the next housing phase or a complete unit can be utilized without advanced planning. For instance, the recovery program in urban areas after the Bam earthquake in 2003 was conducted in three phases: (1) tent shelters, (2) intermediate shelters, and (3) permanent housing (Khazai & Hausler 2005). However, some of Bam's TH, which had been erected on private yards of DP´s previous house, have been reused as a stores or other function in the permanent housing phase. In the second approach, a settlement that had been used for one of the recovery phases can be operated for other phases with or without modification. For instance, after the Lorestan earthquake, in 2006, decision-makers chose tents for DP until finishing the reconstruction phase (Hadafi & Fallahi 2010). Thus, the tents played the role of emergency settlements and TH in the Lorestan recovery program. Additionally, the core housing (nuclear dwelling), as TH approach that has been praised by experts, is assigned in the joint stages group. The core house was used as a temporary and permanent housing project after the central Java earthquake, and it has also been used as a low-cost housing program in Indonesia for decades (Kondo & Maly 2012). Furthermore, TH can even play a transition role or permanent housing when the DP does not desire to leave or cannot return to their permanent housing (Peacock et al. 2007).

In addition, according to Dikmen et al. (2012), post-disaster housing recovery programs can be organized into *top-down* and bottom-*up* approaches in terms of the beneficiaries' roles and organizational forms. The top-down approach is based on governmental decisions and actions without giving a role to DP. This approach is highlighted by standardization and technology-oriented solutions in order to shorten delivery time and minimize public expenditures. However, this approach does not provide other requirements, such as cultural and local conditions (Johnson 2007a). In contrast, the bottom-up approach considers all beneficiaries' requirements by empowering DP (Dikmen et al. 2012); this approach has proven to be more successful in terms of adaptation to culture, local skills, and climate conditions (Johnson 2007a; UNDRO 1982). Therefore, in order to choose one of the two approaches one needs to deliberate on the features and outcomes of each in terms of how these fit to the local characteristics of the specific case, including local potentials, DP characteristics, and so on. Furthermore, Davidson (2009) stated that even for building construction in normal situations, in order to achieve appropriate organizational forms it is necessary to consider stakeholders' characteristics, such as culture. Additionally, it should be emphasized that the organizational strategy has great impact on the supervisors' roles, which is one of the key issues for PDA provision (Gharaati & Davidson 2008).

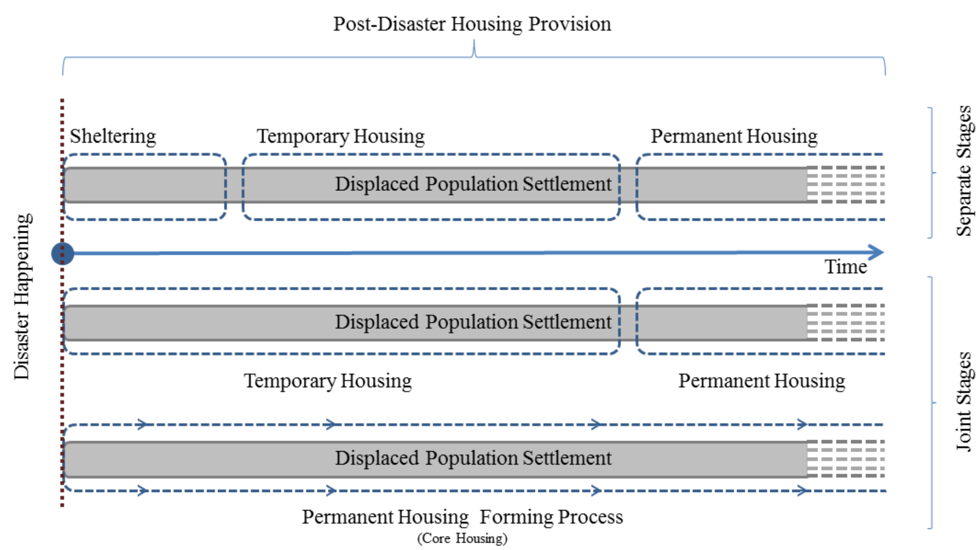

Fig. 3.2. Stages of post-disaster temporary housing approaches

3.4.3. Post-disaster accommodation arrangement

The factors involved in PDA provision, especially TH, from planning to second life, have been considered in PDA arrangement as housing properties. Fig. 3.3 presents PDA arrangement, which includes: the time-scale, provision, and second life of TH. The *time-scale* index embraces different post-disaster phase, diverse requirements, and features of accommodations which must be provided for DP. The *provision styles* index considers the PDA variety in order to provide this accommodation type and associated factors. The *second life* index takes into account the alternative scenarios of using TH after moving DP to the permanent housing.

3.4.3.1. Time-scale

Based on different post-disaster phases defined by Quarantelli (1995) (emergency shelter, temporary shelter, TH, and permanent housing); and beginning times of phases by Johnson et al. (2006) (within hours, a day or two, weeks, and few years, respectively), diverse PDA can be used for each specific purpose. In general, PDA phases differ from each other in terms of the time of the provision process, operation, and also services, which are offered to DP by these accommodations. Meanwhile, the mismatching between mentioned factors has been demonstrated by most researchers as one of the main problems that lead to failed recovery programs.

Some accommodations have the ability to be used for different housing recovery stages especially: tents or winterized tents, which can be applied for emergency shelter, temporary shelter, and TH phases. Additionally, some TH types, which are provided for the TH phase, can be used as a part of/complete permanent housing, such as core housing models. Deciding on the type of accommodations for each housing stage of the recovery process, and the connections between the stages with regard to the actual time period of each phase, can reduce public expenditures and negative environmental impacts.

3.4.3.2. Housing styles

In general, according to (Johnson 2009; Wei et al. 2012), TH can be organized in two main groups; (1) available TH that does not need to be provided, such as available rental apartments and some of collective living quarters, which has been defined by UN, 2013 (United Nations (UN) 2013); and (2) not available TH (NATH) that needs to be constructed, such as mobile housing units (shipping containers, trailers, etc.) and THU. Although, the available PDA has noticeable advantages, such as: immediate delivery time, without material consumption, etc., quality and availability of this accommodation after disaster need to be considered. Additionally, the cost of occupation and maintenance during the DP is living there, as well as the relocation of the DP to the permanent housing need to be evaluated.

3.4.3.3. Site location

Site location, which seems an ordinary factor, has considerable impacts on failing recovery programs and DP´s satisfaction. The social problems due to an unsuitable location normally happens when the DP is forced to move to other areas, because according to (Davis 1978; Johnson 2002), DP prefers to live close to the previous properties, communities, and activities (Aquilino 2011; Johnson 2002).

Site location considers the factors involved in choosing both TH location for available TH and NATH. Site selection is a process that involves many steps from planning to construction, consisting of an initial inventory, alternative analysis, assessment, detailed design, and construction procedures and services (Kelly 2010). Site arrangement takes into account all aspects which need to be designed and provided in a TH site, such as housing location layout, connectivity, facilities, utilities, etc. only for camp approach, NATH.

The NATH site location can be chosen by two approaches: camp (grouped) and yard of DP´ pre-disaster housing (dispersed). Meanwhile, according to the Bam recovery program, 2003 and through interviews with the engineering supervisors of the Bam recovery program from the Housing Foundation of Islamic Republic of Iran (HFIR), TH which had been erected in the private properties was more suitable compared to the planned camps.

3.4.3.4. Not available temporary housing (NATH) construction

Construction system

THUs are often considered as a precast system (Johnson 2009) however, some of THUs have been constructed using on-site masonry construction technology in previous TH programs (Hosseini et al. 2016). Therefore, prefabrication system and on-site construction have been applied for the provision of NATH. According to Félix et al. (2013), precast system of providing NATH, including THUs, mobile housing units, etc., consists of (1) ready-made units that are totally constructed in a factory and moved to the site, such as containers or mobile homes; and (2) supply kits whose elements have been produced in a factory and subsequently assembled on-site.

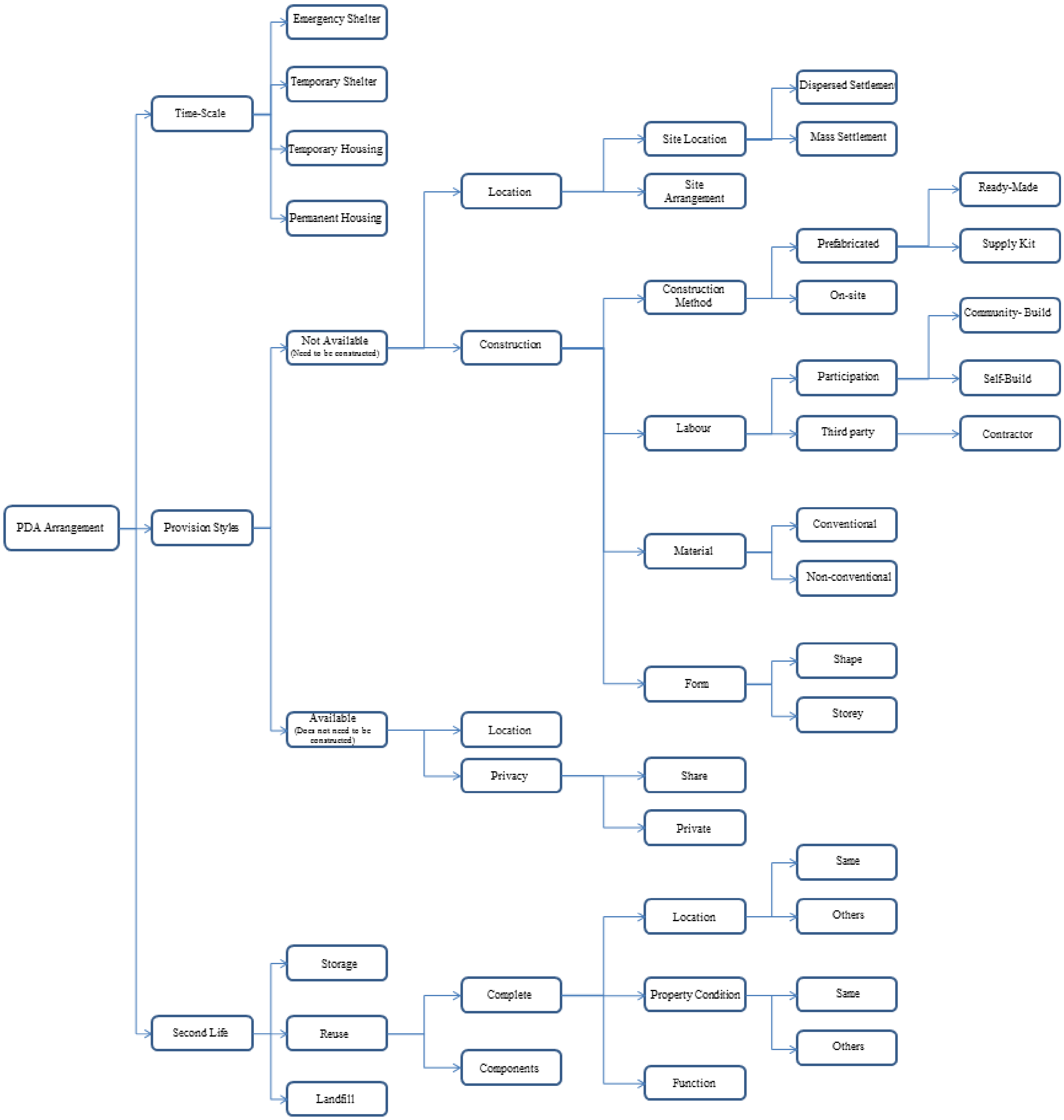

Fig. 3.3. PDA arrangement including use time, provision styles, and second life of PDA

Labour

Decision-makers need to specify the labour methods before determining the construction approach. The Transitional Shelter guideline (2012) considered four labour methods: direct, community, contract, and self-help labour. Meanwhile, as this study focuses more on technical aspects, the labour methods are generally organized into a couple of main categories: participation and third-party labour methods.

The participation method embraces construction approaches when DP only (self-built) or DP with community (semi self-built) undertakes to provide the PDA. However, the community participation in the construction process can go beyond solely being a labour force, and further play a role at other phases (Davidson et al. 2007). This method has been used more frequently for permanent housing construction. However, DP provides unofficial THU, from a separate strategy, as a self-built accommodation when the comprehensive TH provision plan has not been offered by decision-makers. In general, the participation method, which has been planned by experts, has great advantages, as shown in Table 3.2, and has been admired by several researchers however; this method also has some problems which should be considered. Nevertheless, according to Tas et al. (2007), the third-party approach is more frequently used compared to the others in order to provide permanent housing.

The third-party labour method considers the construction approaches to provide DPs´ accommodations by other people without the participation of the DP in the construction process. Although, this method does not consider any role for DP, this method is highly significant for the construction delivery time and quality. However, DP can participate in other parts of PDA provision, such as planning and supervision phases, instead of construction activities. Additionally, sometimes the third-party labour method can only be used in some areas because of DP features, such as: skills, free time, lack of desire, etc. Therefore, based on the mentioned features of the two methods and also the information of Table 3.2, decision-makers need to assess the integration of local characteristics and housing features to determine suitable construction approaches.

Materials and building typology

The materials which have been used for NATH provision can be organized into two categories: (1) *conventional* materials which include the common materials of the permanent building construction industry, such as: wood, steel, cement, etc. and (2) *non-conventional* materials which include materials which are normally not used to construct permanent residential building or rarely used such as: straw bale, earth bags, paper, wooden pallets, etc.

According to Apoport (1969), building typologies have been influenced by climate conditions and culture; therefore, it is necessary to consider local characteristics. NATH is not an exception, the building typology of NATH are almost the same as traditional buildings with row houses (linked house) and detached dwellings, which are single-story or multi storied houses, moreover, with diverse shapes (box, dome, etc.).

Table 3.2. Advantages and disadvantages of participation method

Method	Advantage	Disadvantage	Reference
Participation	(1) increasing DP´s satisfaction, (2) suitable distribution of available resources among DP, (3) modifying TH based on DP´s needs, and (4) increasing feeling of ownership and responsibility consequently, well maintenance	1) increasing construction time, (2) DP needs to learn skills, (3) not fit to DP´s livelihood priorities, (4) decreasing TH qualities, (5) conflict between DP and skilled constructors, (6) lack of certain construction time table, and (7) applicable for the simple construction methods	Arslan & Unlu, 2006; Davidson et al., 2007; Davis, 1978; Kennedy et al., 2008; Ophiyandri et al., 2013; Sadiqi, Coffey, & Trigunarsyah, 2012; Sliwinsky, 2007; Steinberg, 2007

3.4.3.5. Temporary housing second life

TH can normally be used for a maximum of five years in an emergency usage phase, which Johnson (2007a) calls long term use. There are two scenarios for using TH after this time, which Johnson (2009) named the "*second life* of TH; (1) reuse and (2) storage for potential use, such as future post-disaster TH. Moreover, according to (Arslan & Cosgun, 2008; Johnson 2009), there are two diverse approaches for THU reuse; (1) complete building and (2) component usage. In the first approach, complete buildings of THUs can be used in different ways in terms of *location* (same or another location), *property* *condition* (THUs can be sold, rented or donated), and *function* (same or other function). However, using TH on another location and consequently removing THUs, requires a high consideration of the units' infrastructures and their impact. In the second approach, component usage, the components of THUs are used as main building components, raw materials, and recycled materials. Additionally, THUs can be stored for future TH usage, such as the Turkish containers used for the 1999 earthquake in Turkey that were sent to Bam in 2003. However, the cost of THU storage can be extremely expensive over many years (Johnson 2009). Finally, it should be emphasized that those types of TH, which have been available before natural disasters as hotels, can continue their previous functions after the DP leave. Therefore, the second life of these TH is assigned in the complete building group in the same location with a same function, as previously stated.

3.5. Local characteristics

This research organizes the local characteristics into two main groups: (1) *local potentials*, which consider local possibilities of providing temporary accommodation for DP groups based on material and immaterial properties; and (2) *affected population* by natural disaster with different-features which include DP and others. The affected area´s population, which makes up the considerable part of local characteristics, are involve in the recovery program as helpers, including experts, engineers, technicians, workers, etc. or recipients, such as the DP. In other studies, local characteristics have been defined by vulnerability. Blaikie et al. (2014) defined the population's capacity to resist and cope with natural disaster impacts through their level of vulnerability, which is influenced by the population characteristics (Blaikie et al. 2014).

3.5.1. Local potential

Except for the affected population´s features, all other local characteristics, which influence the use of a particular PDA, are mentioned as local potential. To apply each temporary accommodation type there needs to be a match of the affected area´s economic, social, and environmental aspects. Furthermore, the poorly constructed buildings and other weak features of the affected area, which include improper utilities, roads, potential perilous elements, including natural and man-made, etc., are reasons for disasters to happen in the aftermath of natural hazards. Therefore, the local potentials are essential to be assessed in terms of two views: (1) vulnerability of the local population against probabilistic natural hazard and (2) alternative temporary accommodation which can be utilized after the disaster. The local potential factor is broken down in this study into four components: property, attributes, environmental, and technical aspects.

The *property* category considers substantial components of the area, such as buildings including public and private accommodations and services, utilities, facilities, infrastructures, available areas, etc. and their qualities. The *attributes* category takes into account the wide immaterial complex of economic, social, and political characteristics in the area based on numerous factors, such as life standards, livelihood, welfares, cooperative spirit, abilities, etc. The *environmental* aspect embraces climate conditions, geographical aspects, and potential threats. The *technical* aspect considers local abilities to deal with providing temporary and permanent housing related to technical capacities, including: construction methods, skilled/expert human resources, material availability, construction firms and companies, reuse systems, transportation quality, etc.

3.5.2. Affected population

According to Blaikie et al. (2014), some people are more vulnerable in context of differing hazards based on wealth, occupation, gender, disability, health statue, caste, age, immigration status, etc. Additionally, the affected population characteristics, including the mentioned vulnerability factors, culture, abilities, etc., play an important role in PDA provision. For instance, UNDRO (1982) stated the DP of developing countries is better to provide a self-built PDA compared to the industrialized countries. Additionally, Sliwinsky (2007) stated that the participation approach for TH provision can fail due to of DP motivations and characteristics. Therefore, to select a suitable strategy for dealing with a PDA program needs to consider the range of fitting the strategy to DP characteristics. On the other hand, the number of DP has considerable impacts on the decision-making process and choosing the final strategies based on local potentials.

3.6. Natural Disaster

A natural hazard is an event due to geophysical, atmospheric, or hydrological aspects that can cause less or greater harm (Kreimer et al. 2003). Unsuitably dealing with a natural hazard with diverse intensity and severity may become a natural disaster. Natural disaster intensity and severity should be considered despite the fact that, the knowledge for calculating the exact level of a disaster is far from sufficient (Blaikie et al. 2014). Additionally, according to Blaikie et al. (2014), the time of exposure to a natural disaster has considerable impacts on catastrophe vulnerability, and consequently on causalities and DP aftermath of each natural disaster. Nevertheless, other factors that also effect on the DP number which have been considered in the section on local characteristics are: the building quality, occupation, gender, wealth, and so on.

For dealing with natural hazards types, which are categorized into five groups (Geophysical, Meteorological, Hydrological, Climatological, and Biological) by EM-DAT (Jha & Duyne 2010), it is necessary to consider the outcomes of different disaster hazard types (Lindell & Prater 2003), at least for considering the location of PDA among the varieties indexes. For instance, the TH provision strategy of the Bam earthquake in 2003, had been completely different from Japan´s earthquake and tsunami in 2011. In the first case, it was possible to erect THUs in private properties (yard of DP´ pre-disaster housing) meanwhile, DP in some districts of the second case were forced to leave the area, where lived before the disaster, just as those affected-areas by Hurricane Katrina, USA in 2005.

3.7. Case Studies

Five different cases, which faced natural hazards, have been considered. These case studies differ from each other in terms of the three main vertexes, including disasters, PDA, and local characteristics. Almost all approaches of PDA provision have been applied by these five´s programs with different accommodation delivery times, as shown in Table 3.3. The recovery strategies of all cases, except Indonesia, have been based on separate stages with different forms and qualities. However, Indonesia´s recovery program also utilized joint stages partially in addition to the separate stages. The reasons of choosing these case studies is, that these were different in terms of their gross domestic product (GDP), and all case studies are classified in the huge catastrophes groups of the last decades. Alexander (2004) stated that without the consideration of the magnitude of losses, the local financial statue affected area has considerable impacts on its resilience to disaster. Furthermore, both rural and urban areas of the cases had been affected by different natural hazards types. Earthquakes with almost the same magnitudes happened in three of cases: Turkey, Iran, and Italy. One of the cases, Indonesia, was affected by an earthquake and a tsunami, and the last one, USA, by a hurricane and a flood. Moreover, the three of these cases, including Turkey, Indonesia, and USA, faced two natural hazards, the two earthquakes, the earthquake and tsunami, and the hurricane and flood, respectively. In general, these five cases faced the most mentioned problems of TH; moreover, almost all the strategies of PDA provision have been applied by all cases' recovery programs.

Some factors of the three vertexes, presented in Tables 3.3 and 3.5, are assessed to realize the relations of the vertexes' indicators to each other and the outcomes. The strengths and weaknesses of each case are considered based on the individual conditions. The most common problems mentioned by researchers due to the recovery programs of these assessed cases, are as follow: (1) inappropriate delivery time, (2) not matching with DP´s culture, (3) improper organization strategy, and (4) strategy shortfalls in dealing with tenants. The individual problems of each case are determined in the Table 3.4.

3.7.1. Turkey, 1999

In the wake of the earthquake happening in the Marmara region of Turkey on August 17th, 1999, 73342 buildings were collapsed or badly damaged (Akinci 2004). The same damage happened in the wake of the Duzce earthquake, Mw= 7.2, which took place on November 12th. The economic loss caused by the amount of buildings in these two earthquakes was about $5 billion (Erdik 2000). The government responded to the DP´s accommodation need in three phases, which were (1) tents, (2) prefabricated TH, and (3) permanent housing (Johnson 2007 b). Other strategies, such as self-built accommodations and rental subside were also applied (Johnson 2007a). Meanwhile, 10% of THUs had been occupied six years after the Duzce earthquake (Arslan & Unlu 2006). Most of the 43,053 permanent buildings have been provided by the two ministries and the others by the various intuitions (Tas et al. 2007). In general, the post-disaster housing provision after the Turkey earthquakes of 1999, were applied with the minimum DP participation which caused some problems, of unsuitable maintenance. Nevertheless, the Turkish government decided to provide this large amount of THUs because 180,000-240,000 people were living in tents and tight rental market while, winter was coming (Johnson 2007a).

Table 3.3. The five case studies´ natural hazards and post-disaster housing types

Case study	Natural hazard: Type	Natural hazard: Intensity	Post-disaster accommodation: Type	Post-disaster accommodation: Timing [(a)] (week 2 4 6 8 | month 4 6 8 10 12 | year 2 3 4 5)	
Turkey 1999	Earthquake	Mw=7.4 Mw=7.2	Tent		(1)
			NATH		
			PH [(b)]		
Iran 2003	Earthquake	Ms=6.5	Tent		(2)
			NATH		
			PH		
Indonesia 2004	Earthquake Tsunami	Mw=9.2	Tent & barrack		(3)
			TH [(c)]		
			PH		
USA 2005	Hurricane Flood	Category 3 [(d)]	shelters		(4)
			TH [(c)]		
			PH		
Italy 2009	Earthquake	Mw=6.3	Winterized tent		(5)
			Semi-/PH		

[(a)] For temporary accommodation, provision start and DP leaving time are considered, reconstruction start and finishing time for permanent housing. Additionally, this time table has been conducted based on general process meanwhile, timing of specific examples could be different form this table. For instance, Tafti, and Tomlinson (2013) presented a specific case which the owner was living in TH until 2011 (about eight years after the disaster) in Bam. Also, THUs of Turkey housing program were used by tenants and new migrants until 2005, when the government forced the THUs users to leave by cutting off the services (Johnson, 2007 b).

[(b)] Permanent housing

[(c)] As some emergency shelters were also used as TH after emergencies, the beginning time of TH use cannot be specified.

[(d)] Category storm on the Saffir-Simpson Scale by (Chandler, 2007) and category 5 on 28th August by (Nigg, Barnshaw, & Torres, 2006)

(1) Johnson, 2002, 2007 b; (2) Ghafory-Ashtiany & Hosseini, 2008; Khazai & Hausler, 2005; (3) IFRC, 2007; Matsumaru et al.,2012; Steinberg, 2007; (4) Chandler, 2007; Kates et al., 2006; and (5) Özerdem & Rufini, 2013; Rossetto et al., 2014

Table 3.4. Particular problems of the five cases

Case	Problem	Reference
Turkey (1999)	(1) improper site location, (2) not fitting THUs use time and durability, (3) unplanned second life of THUs, (4) consuming permanent housing sources by THUs, (5) negative impacts on environment, and (6) shortfall in facilities	Arslan & Unlu, 2006; Tas, Cosgun, & Tas, 2007; Johnson, 2007a,b
Iran (2003)	(1) not fitting to climate conditions, (2) improper site location, (3) Indistinguishable DP from post-disaster immigrant, (4) not receiving THU at the same time, and (5) inappropriate materials durability	Fayazi & Lizarralde, 2013; Ghafory-Ashtiany & Hosseini, 2008
Indonesia (2004)	(1) complexity of organizations' tasks which were involved in recovery program, (2) some organizations were not specialized in reconstruction of housing, (3) poor units performance, (4) site location problems, (5) insufficient considering to infrastructures provision, (6) insufficient coordination between agencies, and (7) shortfall in materials	Da Silva, 2010; Doocy et al., 2006; Steinberg, 2007
USA (2005)	(1) dispersal of DP, (2) transition DP from one of the four-phase typology to other one in a disarranged way, (3) shortage of rental units, (4) using buildings with inadequate features for sheltering functions, (5) delay on utilities provision, and (6) negative environmental impacts	Chandler, 2007; McCarthy , 2008; Nigg, Barnshaw, & Torres, 2006
Italy (2009)	(1) losing pre-exited communities and consequently psychological problems, (2) inadequate facilities, (3) lack of local participation, (4) improper site location, (5) negative environmental impacts, (6) expensive building construction, (7) delay in reconstruction, and (8) the pre-disaster houses became second homes for temporal using	Alexander, 2010; Özerdem & Rufini, 2013; Rossetto et al., 2014

3.7.2. Iran, 2003

After the Bam earthquake in December 26th, 2003, more than 90% of buildings in the urban areas were destroyed (Fayazi & Lizarralde 2013). Regarding the Bam temporary accommodation provision, tents and NATH, including prefabricated and in-situ units, with both approaches of allocations, camp (grouped) and yard of DP´ housing (dispersed), were used. There were more than 50,000 tents erected by The Iran Red Crescent Society as temporary shelter the first day of the earthquake (Ghafory-Ashtiany & Hosseini 2008).

The cost of the Bam prefabricated THU, whose area was 16-20 m^2, was about $2500-$3000 (Khazai& Hausler 2005). The different THU types, such as pre-fabricated and masonry technology were provided on camp site and on the yard of pre-disaster private buildings. Indeed, the strategy camp site changed into a private yard of DP due to the rejection of THUs by the DP. Khazai and Hausler (2005) stated that the distance of THUs from the DP´s pre-disaster properties was one of the reasons to refuse their use. Therefore, from 35,905 THUs, 9,005 were erected on camp site and 26,900 on DP´s private properties (Ghafory-Ashtiany & Hosseini 2008). All of the THUs which have been erected on the private property became permanent while, only the THUs constructed with masonry technologies and materials were applied as living space (Fayazi & Lizarralde 2013).

3.7.3. Indonesia, 2004

In the wake of the earthquake and tsunami which happened on December 26th in Indonesia, approximately 220,000 lives were lost and 10,000 people were injured (Steinberg 2007). To provide post disaster accommodations after the Aceh earthquake, different approaches were applied, there were self-help systems and third-parties. Most of the organizations involved in the recovery program initially intended to apply self- or community-built programmes (Da Silva 2010). These programs were implemented with different approaches, such as cash for work, which was a logical mechanism to engage the population in community-building programs (Doocy et al. 2006). Firstly, decision-makers preferred to bridge between sheltering and permanent housing, and consequently DP resided in tents and barracks. However, the government could not achieve this goal completely. Da Silva (2010) stated after one year, that only less than half of the population considered were housed in barracks. The decision-makers offered 36 m^2 permanent housing for free which needed to be extended by the DP after the buildings were handed over as core housing.

3.7.4. USA, 2005

The aftermath of Hurricane Katrina, which happened on August 29th in New Orleans, USA, 1,570 people lost their lives and $40-50 billion were lost (Kates et al. 2006). In general, Hurricane Katrina made 770,000 DP and more than 305,000 severely damaged buildings (Weiss 2006). The four-phase typology developed by Quarantelli (1995) has almost been applied to settle the DP due to Hurricane Katrina (before happening as evacuation shelters to permanent housing). However, some cases have been more dynamic and fluid than this typology arrangement (Nigg et al. 2006). Thus, the pre/post-disaster shelters that were provided included the Superdome, the Convention Center, evacuation centres by the American Red Cross, the Reliant Arena, hotels, and rental homes. In addition to the mobile homes and trailers, some of these shelters became TH. Some of the DP, who were placed in motel/hotels in 48 states and in approximately 67,000 apartments in 32 states (McCarthy 2008), were as far as 250 miles from their pre-disaster homes during the emergency phase (Nigg et al. 2006).

3.7.5. Italy, 2009

An earthquake, a medium-power seismic event, happened in L'Aquila, Italy, on April 6th which caused 308 deaths and 67,500 DP (Alexander 2010). For this case’s recovery program, like Aceh, transition directly from emergency shelter to permanent housing has been decided and decision-makers partially concealed the intermediate stage. Therefore, the emergency shelter usage time purposely lengthened due to construction of high standard transitional housing (Rossetto et al. 2014). According to Alexander (2010), DP was almost evenly placed in three different ways: hotels, tent camp, and other accommodation types on their own initiative. The DP kept in the hotels and tents during summer (Alexander 2011a). To provide semi-/permanent housing, C.A.S.E project, Anti-seismic, Sustainable and Ecologically Compatible Housing Complexes as new towns, with a maximum capacity of 17,000 inhabitants and MAP project, temporary housing prefab, including 2,262 units were accomplished housing (Rossetto et al. 2014). The first delivered semi-/permanent buildings were used by 200 DP 167 days after the earthquake (Özerdem & Rufini 2013). The recovery strategy in the wake of L'Aquila earthquake designed by the government had problems in terms of economic, social, and environmental aspects (Alexander 2010; Fois & Forino 2014). However, the local potentials such as building construction industry were able to provide these accommodations with great speed based on the required standards.

3.8. Discussion

The assessed cases confirm how the three main vertexes (local characteristics, natural disasters, and PDA properties) led the cases' results. However, sometimes the vertexes had antithetical impacts on the cases. For example, Arslan and Unlu (2006) noted that people who had an insufficient income level, migrated to the Duzce earthquake-affected areas because of free foods and shelter. The migration of non-affected population from outside of Bam city also happened after the Bam earthquake. Meanwhile, after Hurricane Katrina, some of DP did not desire to return to New Orleans thus, the population of New Orleans was 36% of pre-Katrina population after five months of the hazard happening (Kates et al. 2006). In general, different DP characteristics resulted in diverse migration trends to the affected area.

Additionally, PDA provision approaches, which are rejected by most researchers, can be suitable for a case, and vice versa. In other words, it depends on the priorities of each case´s requirements so that a strategy can be applied. In this regard, Steinberg (2007) stated that prefabricated housing can assist to improve housing quality and resistance to earthquake in Indonesia due to the poor quality of the built housing. However, initially this approach was supposed to be avoided because of some reasons, such as the participation of DP in all phases and the decision to invest money on permanent housing rather than TH. To this end, the self- or community-built program was applied in Aceh although, shortfalls in skilled labour even in pre-disaster had impact on this decision. However, DP did not desire to have corporate housing provision when some agencies started to employ contractors for constructing buildings (Da Silva, 2010), and consequently many agencies changed the initial strategy when faced to some problems. Therefore, each previous strategy, regardless of the outcomes, has been chosen based on local characteristics, such as Indonesian authorities decided to apply self- or a community-built program by considering the local potentials and DP characteristics. As another example, the Turkey recovery program which utilized THUs because of DP numbers and the intolerable climate conditions.

The Indonesian DP in 2004, had to move to TH or semi-permanent housing due to the decline of the tents under the tropical sun and rain (Da Silva 2010; Steinberg 2007). Therefore, tents can be a cheap and quick approach to reside DP however, they may not be ideal to be used for each climate condition and can cause to duplicate temporary accommodation provision. Furthermore, since some of the high quality THUs were the cause of DP´s dissatisfaction and were rejected, the life standard of DP needs to be considered for acceptance of tents or any PDA type. It should be emphasized that the quality life of DP, which can be related to GPD per capita, as shown in Table 3.5, demonstrates the TH quality from the view point of DP. Indeed, the TH quality is derived from the integration of DP´s expectations and the unit's properties. In other words, TH types, which are rejected by a case´s DP, can be high-quality housing for another case´s DP. For instance, the trailers of the Katrina recovery program were not a perfect solution for returning DP (McCarthy et al. 2006) despite the fact that the trailers quality can be considerably higher than THUs of another case.

In sum, TH quality needs to be considered in comparison to the pre-disaster housing of the DP. Similarity, Da Silva (2010) stated that some transitional shelters which were applied in Aceh, were more appropriate than semi-permanent or permanent housing which existed before the natural disaster. Additionally, sometimes the THUs with high-quality technology which are more adequate for post-disaster accommodations in terms of delivery time, strengths, and so on, are rejected by DP owing to cultural non-acceptance. For instance, the DP of Bam refused the 3D sandwich panel technologies due to cultural reasons. Also same situations occurred for the light weight blocks system, which required

Table 3.5. The six case studies´ local characteristics

Case study	Local potential								Affected population				References
	Building			Prosperity (2011)		Climate condition					DP		
	TECH Pre-Disaster	SD/CB (Nº)	SD/CB (%)	GDP per capita [a] ($)	HDI [a]	MIN TEMP (C)	MAX TEMP (C)	Rainfall (AVG./year) (mm)	Population	Death	(Nº)	(%)	
Turkey 1999	Reinforced Concrete	93618 [b]	NA	13668	0.699	3.6 [c]	26 [c]	665.7 [c]	2300000	18373	300000+	13	Cosgun, & Tas, 2007; Erdik, 2000; Klugman, 2011; Unal, Kindap, & Karaca., 2003
Iran 2003	Brick and Steel, Adobe,	52756 [d]	80	11558	0.707	-2	44	62.5	142376 [d]	31383	65000 [e]	50	Ghafory-Ashtiany & Hosseini, 2008; Klugman, 2011
Indonesia 2004	Timber, Brick	116880	57	4199	0.617	22	34	1600 [f]	4000000	167000	500000	12.5	Da Silva, 2010; IFRC, 2007; Klugman, 2011; Sari, 2011; Steinberg, 2007
USA 2005	Timber, Brick, Others	134344	72	45989	0.910	9	29	1520	460000	1570	253000 [g]	59	Boyd et al., 2004; Chandler, 2007; FEMA, 2006; Kates, et al.,2006; Klugman, 2011; McCarthy, 2008
Italy 2009	Masonry, Steel, RC	60000	NA	32430	0.874	-2	29	702	72800 [h]	308	67500	NA	Alexander, 2010; Klugman, 2011; Rossetto et al., 2009

[a] Country

[b] According to Johnson (2007) the number of inhabitable units (Johnson, 2007 b) meanwhile, the collapsed buildings almost were 16400 (Erdik, 2000).

[c] Marmara region

[d] Urban and rural population of Bam in 1996

[e] Khazai and Hausler (2005) stated the all number of people, including population of Bam and surrounding villages, and migrants, who needed to shelters were 155000.

[f] On coast

[g] 273000 evacuees in peak time (McCarthy, 2008) meanwhile, 1.2 million people left their homes because of Hurricane Katrina (Nigg, Barnshaw, & Torres, 2006). Additionally, based on McCarthy et al. (2006), the homes of 55% of New Orleans' population were severely damaged (McCarthy et al., 2006). Thus DP of New Orleans was almost 253000.

[h] L'Aquila population. Additionally, Rossetto et al. (2009) stated that DP of L'Aquila was almost 17000. Thus, it can be concluded the ratio of DP to all city population was approximately 23% in L'Aquila

Additionally, according to Da Silva (2010), the recovery program of Aceh led to long delivery, higher expenses, and poor quality due to the fact that the strategy was changed several times and different technologies were applied. Therefore, unsuitable outcomes are not only derived from PDA approaches, but tend to happen when there is no explicit planned approach, and decision-makers do not consider, the short- and long-terms results, as well as the limitations based on local characteristics and natural hazard. For instance, in the aftermath of the Aceh earthquake and tsunami, some site location of DP´s prior housing could not be used. In earthquake-affected areas, this situation does not usually happen, for example, the authorities of the Bam recovery program could erect THUs in private properties.

Therefore, the other vertex which needs to be considered is the characteristics of natural hazard, such as hazard types, intensity, etc. In the case of the Katrina recovery program, the decision-makers were placed with a dilemma because NATH, mobile homes and trailers could not be located in flood plains in order to avoid future hazards. On the other hand, the DP needed to be in proximity to their pre-disaster properties (McCarthy 2008). However, in order to provide NATH in proximity to the affected-areas, they needed to wait until the area was pumped dry, which was done by the 20th of September (Chandler 2007). Furthermore, emergency managers could use hotels and rental units, which were resistant to Hurricane pre-disaster, as many tourists were evacuated to high-rise hotels in New Orleans (Nigg et al. 2006).

These cases illustrate the use of different approaches, including more acclaimed as well as criticized strategies, which led to obtain divers outcomes. Some applied strategies, even acclaimed ones, yielded weak outcomes not only exclusively due to the implemented approach, but due to the approach being unsuitable to other local input. Additionally, sometimes due to special conditions of each case, authorities force to apply types of TH, which are identified with considerable negative impacts by most researchers. However, the negative features of these types can be lessened by considering all corresponding factors. For instance, the suitable second life of THUs can be granted, if the integration of TH quality and local characteristics, such as forthcoming requirements, cultural aspects, climate condition, and so on, are considered.

In general, it can be deduced that none of the approaches which have been applied for PDA provisions is completely perfect thus, it seems logical to affirm that the most adequate approach should be based on the specific conditions of each case. Indeed, the approach appropriateness or inappropriateness can be realized based on the case´s requirements. Thus, some concerns for temporary accommodation provision of one area are not considered nor are determined for another area. Nevertheless, the three main vertexes constitute the main strategies of all the cases recovery programs however, all with diverse impacts and outcomes. Therefore, to determine a suitable strategy for each case, decision-makers need to realize the outcomes of using each strategy by considering the local characteristics of the case. To this end, it is necessary to define organizationally all factors, which have been accomplished in prior sections of this research as the three main vertexes, and the factors of interconnections.

3.9. Findings

As aforementioned, the TH stage cannot be concealed. However, some types of PDA, which have notable negative impacts such as THUs, can be replaced with another accommodation type or can be modified. Indeed, the diverse approaches for providing PDA are not all perfect or imperfect, moreover; it is essential to consider the integration of all factors. To this end, almost all associated elements, which can have linear and non-linear relations to members of a group and other vertexes groups, to PDA have been organized into the main vertexes, with diverse impacts on the cases. Thus, this study presents a customizable platform which is able to be applied for each case with regard to the findings from analysing the case studies. The proposed strategy includes two parts: (1) choice phases consisting of decision phases, involved factors in each stage, and their relationships; and (2) the algorithm of the decision-making process.

In the aftermath of a natural disaster, authorities are confronted with a decision-making process in order to provide PDA, which includes different choices and stages. The results of each recovery case are obtained from the outcomes of these stages, which can generally be organized into three parts: as a general PDA approach, operation, and second life phases, as shown in Fig. 3.4. Although, the general PDA phase seems to be located before the operation phase, which in itself contains four separate choices stages, and the second life choice phase; the final approach is extracted from the integration of these stages.

The choice phases contain different elements which have already been defined in the three main vertexes, and these stages expose the explicit connections of the elements for decision-makers. However, these choice stages may need to be improved by determining priorities of indicators or/and adding new specific indicators based on individual characteristics of each case by local experts. Although the choice phases have designed to choose suitable alternative before the natural disaster taking place, this can be improved based on the real data which is obtained after natural disaster according to the algorithm designed by Johnson (2007b).

As shown in Fig. 3.4, each choice phase includes diverse indicators which are assigned to the three vertexes. The factors are covered with different line types as solid, dash dot, and dot, which demonstrate that each factor belongs to a vertex; local characteristics, natural disasters, and PDA properties, respectively. Sometimes an indicator of these stages, which is obtained from the integration of the two/three vertexes, is covered with one of the two/three shapes. For instance, the damage amount indicator, which is determined by jointly considering local and natural hazards characteristics, has been covered by two rectangles (solid and dash dot lines). Therefore, the sources of the indicator are specified for decision-makers to realize the interconnections of the indicators. However, to apply these for determining the suitable PDA alternatives it is necessary to define the decision-making model.

To this end, the decision-making process algorithm for selecting suitable PDA is presented in Fig. 3.5. In general, this decision-making model embraces two main parts; filtering and comparing. The Filtering section, which contains Conditions and Availability sectors, is the initial screen phase for selecting PDA. The Filtering takes into account the alternative availability. Indeed, this section of the model considers whether the alternative PDA exits in the affected area or can be provided. Also, the Conditions part probes required infrastructures and conditions for utilizing each alternative by assessing local and TH characteristics with regard to the material and immaterial aspects. In the second screening phase, the detailed technical indicators are applied to assess acceptable/available alternatives based on economic, social, and environmental impacts by considering exclusive local features and demands to distinguish most suitable alternative(s) among all options.

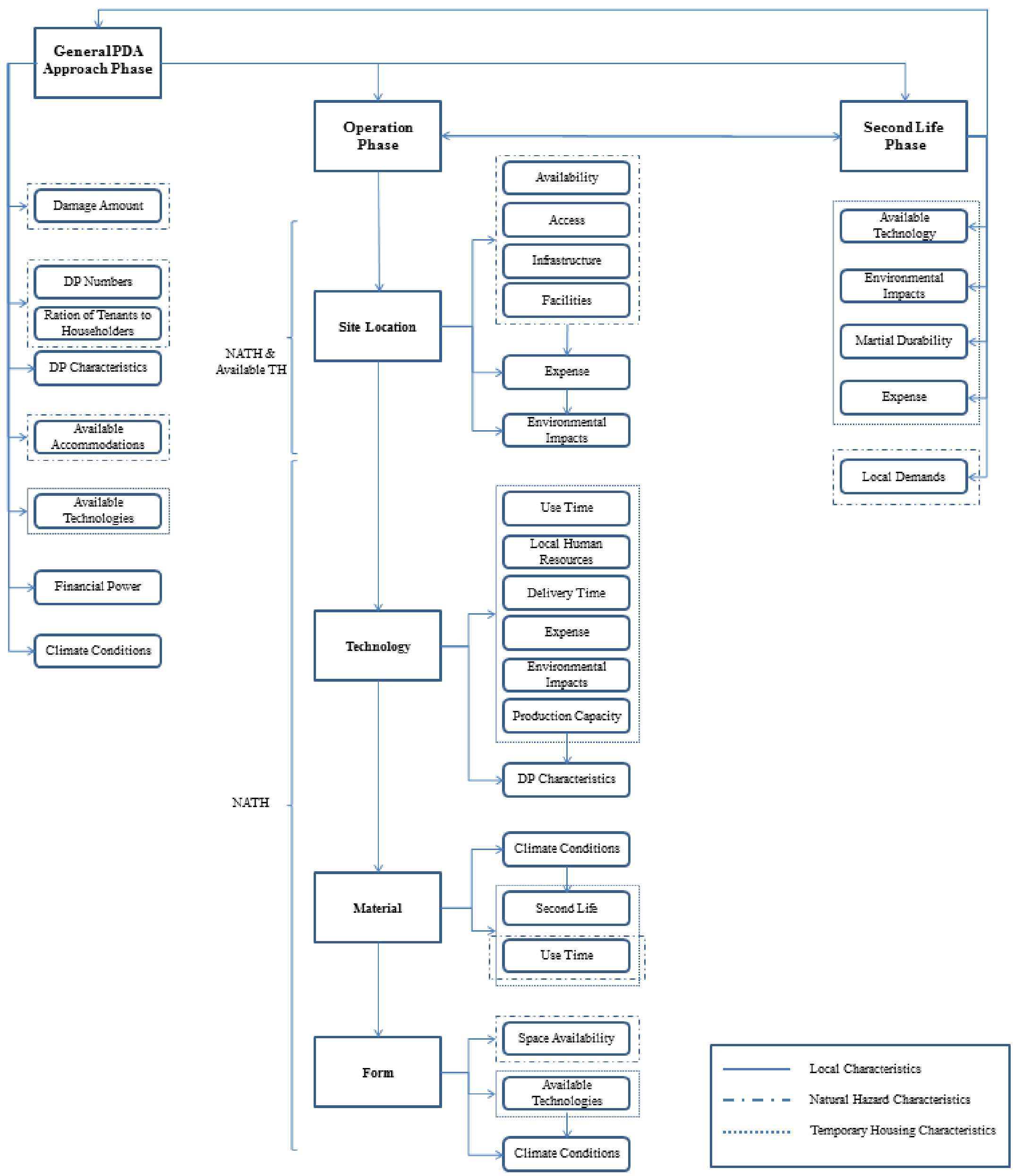

Fig 3.4. The choice phases of PDA including the elements and connections

To apply the two phases of selecting suitable PDA from the model presented needs to determine the choice stages and the elements involved which are shown in Fig. 3.4. In this regard, all elements, which are required for considering PDA, have been defined in the three vertexes as the main data bases. In the end, decision-makers have the ability to deal with PDA for each specific case by applying the strategy presented, which are derived from this study by simplifying the complicated PDA issue into explicit steps and characteristics.

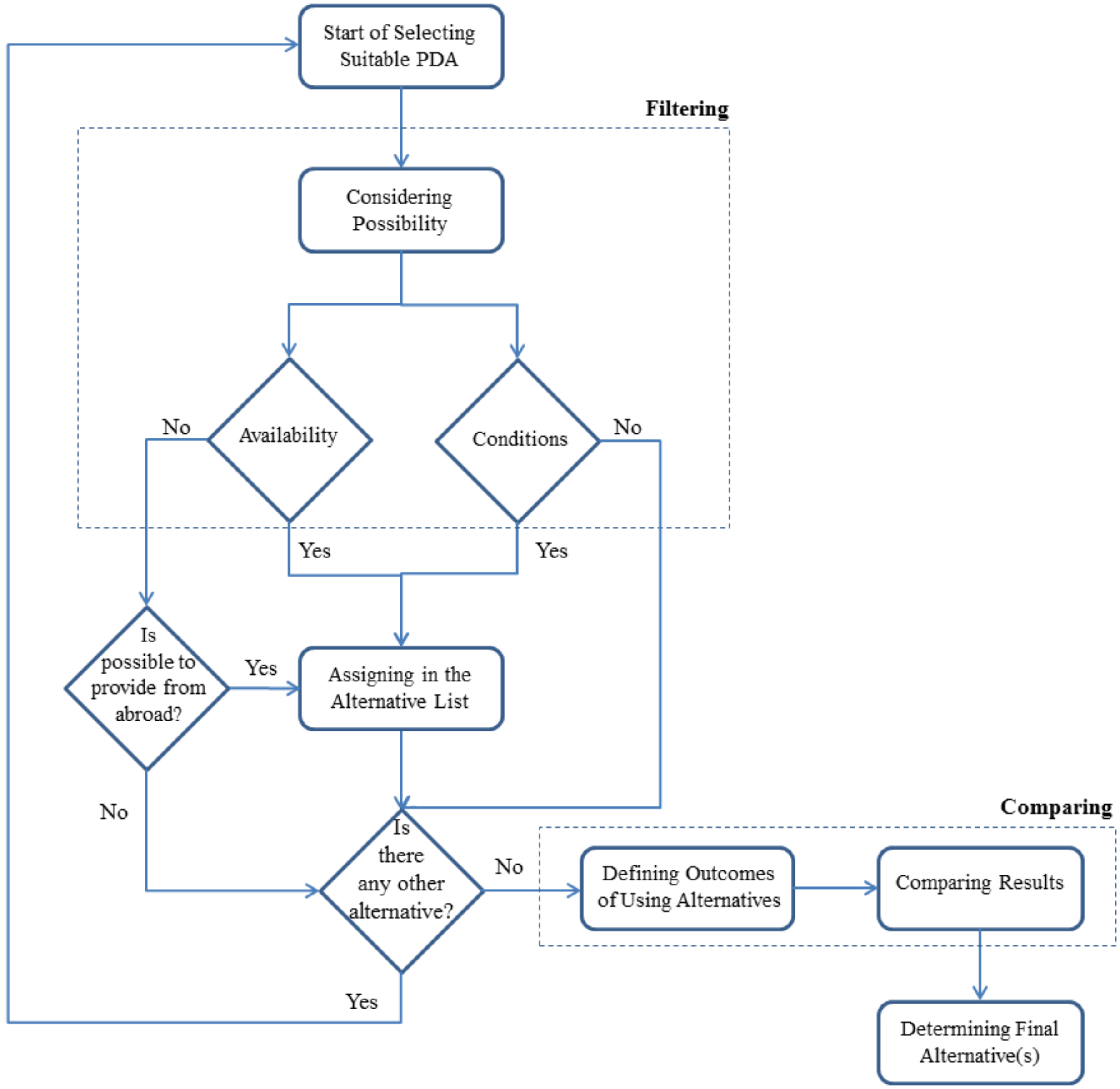

Fig 3.5. Decision-making process algorithm of PDA

3.10. Conclusion

This research presents a new strategy to deal with a temporary accommodation provision program for decision-makers based on customizing effective factors. To this end, the strategy allows to distinguish all intertwined elements involved for PDA provision through three main vertexes (local characteristics, natural disasters, and PDA properties) and other inherent aspects gathered within these vertexes. In addition, the choice phases, which include these elements and the interconnections, have been defined. Finally, a customizable model was proposed to carry out a PDA selection process. The method proposed in this research is aimed at assisting decision-makers to select suitable PDA by simplifying the general problem in: consequences, limitations, potential responses-reactions and the main vertexes.

These vertexes and the outcomes of the considered recovery programs were identified in five different real cases. The conclusions derived from this analysis are:

- A direct relationship between stakeholder's satisfaction and the local initial conditions (e.g., prosperity and welfare of the affected area, pre-disaster housing) is difficult to be established. In this regard, the PDA outcomes seem to be rather dependant on the suitable integration of these elements.
- The impacts of these elements on the recovery program outcomes differ from one case to another; even, same aspects can lead to antithetical effects depending on the case.

This study brings to light the need to integrate the priorities of the different stakeholders involved in the recovery process in order to guarantee its success. In this regard, the vertexes and the involved elements should be identified and assessed for each particular case. To this end, representative and objective importance, aiming at satisfying the stakeholders, must be assigned to each element. This is considered as a future research task that could be carried out introducing the concept of sustainability understood as the balance between economic, environmental and social needs.

Chapter 4

Considering the Sustainability of Post-Disaster housing: Limitations and Requirements

4.1. Introduction

Construction industry consumes 24% of the raw material extracted from the earth (Bribia et al. 2009). Additionally, the buildings cause more than 30% of all annual range of green gas emissions and consume than the 40% of the global energy consumed (Sustainable Buildings and Climate Initiative (Sbci UNEP) 2009). Therefore, it is evident that this sector generates considerable environmental impacts that must be born in mind. The factor, natural hazards, compels the building industry to accelerate more and consequently, the negative effects increase even more. This undesired situation in terms of environmental, economic, and social aspects boosts global climate change effects and, at the same time, the characteristics of future natural hazards such as intensity, timing, frequency, types (Field 2012) (cited by (Banholzer et al. 2014)). In parallel, the population living in the areas prone to the natural hazards grows (Lall & Deichmann 2009). Additionally, low-quality accommodations as inner city, slums and current DP around the world are required to be added to the aforementioned concerns.

Regardless of the existent problems, DP who lost their home in the wake of natural disasters need somewhere to recover the normality of pre-disaster situation (Davis 1978). This need could be solved by means of temporary and permanent housing. Meanwhile, the short-term requirements should not be cause of forgetting the long-terms requirements and those aspects associated to sustainability. In this sense, the disaster management needs to change the response and recovery strategy to sustainable hazard mitigation (Pearce 2003) (cited by (Hayles 2010)). Furthermore, Nakagawa & Shaw (2004) stated that natural disasters could be opportunities for sustainable reconstruction. Beyond the abovementioned facts, high-quality sustainable buildings is a human rights (Schneider 2012). Meanwhile, there are only few studies in which this issue particular issue has been dealt with; however, an increasing publication trend in relation with this topic is being observed.

This chapter aims at considering sustainability of PDH to design an explicit platform for decision-makers to figure out how to deal with this essential issue. In general, the main questions proposed for this part of the research are:

- Why is necessary to consider sustainability of PDH?
- What is the sustainability of PDH?
- How sustainability of PDH can be assessed?
- Which are the research suggestions for future studies on this area?

Thus, the previous researches in this area are considered in this study and this presents the answers to the aforementioned questions. Additionally, PDH embraces two phases of the four phases of recovery programs defined by (Quarantelli 1995) for dealing with post-disaster accommodations: temporary housing (TH) and permanent housing. This study focuses rather on TH however; these two cannot be detachable in many cases, such as core housing strategy. Therefore, the term of *PDH* is used for all type of TH that could be used for TH and permanent housing.

4.2. Research background

Although the trends of publications on disaster research is increasing, the number of published studies in academic journals related to the sustainability of PDH is still not representative. For instance, according to Yi and Yang (2014), the paper of (Kennedy et al. 2008), *The Meaning of 'Build Back Better': Evidence from Post-Tsunami Aceh and Sri Lanka*, had been cited thirty four times in 2014 (Yi & Yang 2014) meanwhile, the Wiley online library displays seventy citations number of this paper. However, Scopus shows that this paper has cited eighty seven times till the April of 2016. Therefore, the citations number of this paper has increased more than twice and half during approximately two years. The other research papers assessed by Yi & Yang (2014) in terms of citation frequency have been compared based on current citations, as shown in Fig. 4.1. This citation increasing trends also could confirm the considerable amount of publication related to PDH during only few couple of years. Still, considering the relevance of the topic, the research carry out on this is not enough representatives.

Additionally, this study considers the four scientific research sources (Science Direct, Emerald Insight, ACSE, and Wiley) to determine the number of published papers focused on sustainability of PDH between 2004 and 2016. To this end, in order to obtain potential papers the terms of *sustainability*, *post-disaster*, and *housing* is searched through paper title, abstract, and keywords. The results highlight that nineteen papers have been published during these twelve years on different research lines, as shown in Table 4.1.

It should be emphasized that some published researches consider sustainability of PDH meanwhile; these studies are not include in Table 4.1. These papers with higher cited number that are conducted based on PDH sustainability directly/indirectly are listed in Table 4.2.

4.3. Sustainability of post-disaster housing

4.3.1. Definition

The sustainability of PDH has been defined in different ways by researchers. Roseberry (2008) indicated that sustainable construction embraces economic, social, and environmental aspects that is required to be considered from planning to monitoring phase.

In this regard, Hayles (2010) stated that sustainability concept changes the focus on medium to long-term process; thus, all process involved in a recovery program should fit the requirements of DP in order to achieve the sustainability. Schneider (2012) also considered these three main vertexes of sustainability as the differences of the conventional and sustainable constructions.

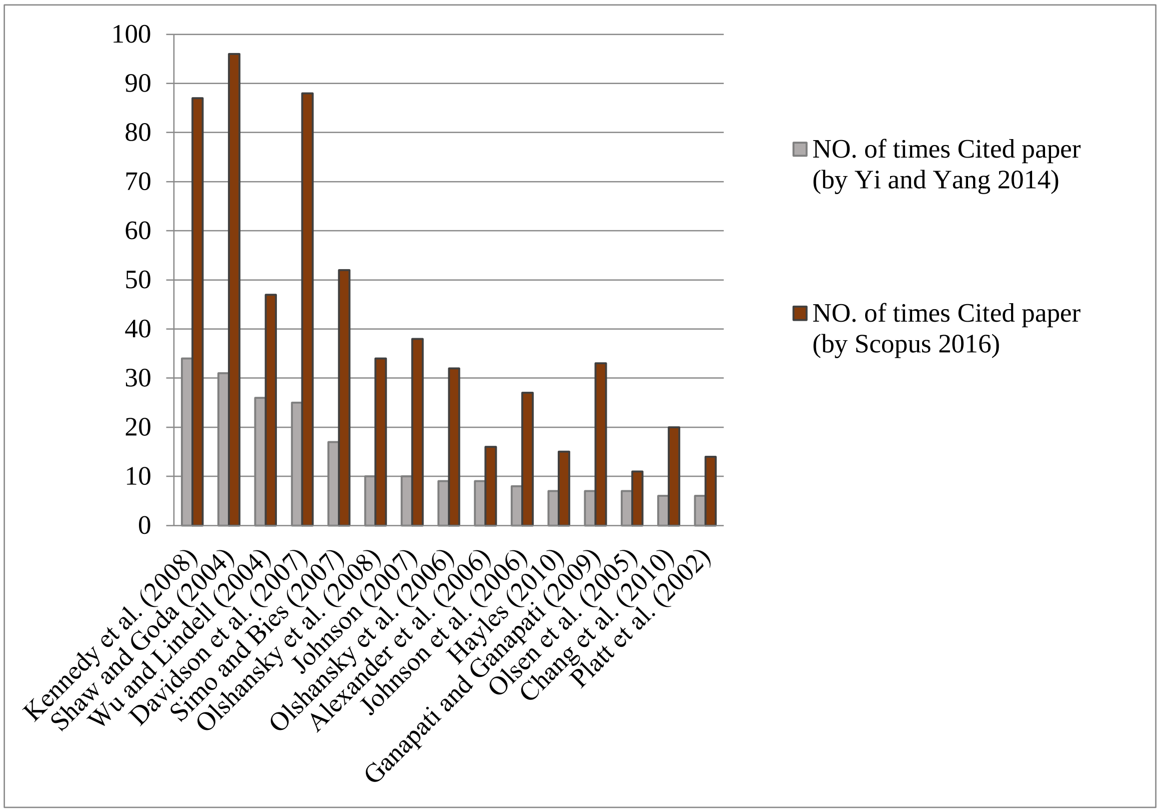

Fig. 4.1. Comparison of citations times of different papers on PDH according Yi and Yang (till 2014) and Scopus (till 2016)

Table 4.1. Publications of four research academic publishing companies (APC) from 2004 to 2016

ACP	Author	Paper Title	Year of publication	Journal title
ACSE	Hosseini et al.	Multicriteria Decision-Making Method for Sustainable Site Location of Post-Disaster Temporary Housing in Urban Areas	2016	Construction Engineering and Management
	El-Anwar et al.	An Automated System for Optimizing Temporary Housing Arrangements after Natural Disasters	2009	Construction Research Congress 2009

ACP	Author	Paper Title	Year of publication	Journal title
	Arslan and Cosgun	Reuse and recycle potentials of the temporary houses after occupancy: Example of Duzce, Turkey	2008	Building and Environment
	Félix et al.	Temporary housing after disasters: A state of the art survey	2013	Habitat International
	David Seño	How sustainable are the Philippines-based housing donor programs? A multi-disciplinary perspective	2014	Procedia Economics and Finance
	Parva and Rahimian	Transformability as a Factor of Sustainability in Post-earthquake Houses in Iran: The Case Study of Lar City	2014	Procedia Economics and Finance
Science Direct	Moles et al.	From Local Building Practices to Vulnerability Reduction: Building Resilience through Existing Resources, Knowledge and Know-how	2014	Procedia Economics and Finance
	Peng	A comparison of two approaches to develop concentrated rural settlements after the 5.12 Sichuan Earthquake in China	2015	Habitat International
	Potangaroa	Sustainability by Design: The Challenge of Shelter in Post Disaster Reconstruction	2015	procedia – social and behavioral sciences
	Escamilla and Habert	Global or local construction materials for post-disaster reconstruction? Sustainability assessment of twenty post-disaster shelter designs	2015	Building and Environment
	Hosseini et al.	Multi-criteria decision-making method for assessing the sustainability of post-disaster temporary housing units technologies: A case study in Bam, 2003	2016	Sustainable Cities and Society
	Tucker et al.	Some design aspects of sustainable post-disaster housing	2014	Disaster Resilience in the Built Environment
Wiley	Fois and Forino	The self-built ecovillage in L'Aquila, Italy: community resilience as a grassroots response to environmental shock	2014	Disasters

ACP	Author	Paper Title	Year of publication	Journal title
Emerald Insight	Hayles	An examination of decision making in post disaster housing reconstruction	2010	Disaster Resilience in the Built Environment
	Rosowsky	Recovery: rebuilding a resilient housing stock	2011	Disaster Resilience in the Built Environment
	Bornstein et al.	Framing responses to post-earthquake Haiti: How representations ofdisasters, reconstruction and human settlements shape resilience	2013	Disaster Resilience in the Built Environment
	Wiek et al.	Challenges of sustainable recovery processes in tsunami affected communities	2010	Disaster Prevention and Management: An International Journal
	Zuo et al.	A project management prospective in achieving a sustainable supply chain for timber procurement in Banda Aceh, Indonesia	2009	Managing Projects in Business
	Javernick-Will et al.	A qualitative comparative analysis of neighborhood recovery following Hurricane Katrina	2012	International Journal of Disaster Resilience in the Built Environment

In general, it could be affirmed that sustainability is achieved from the optimized integration of these three vertexes (economic, social, and environmental). In order to obtain suitable outcomes each particular case should be decoupled in two aspects: (1) how to achieve maximum satisfaction in each indicator considered, and (2) optimize the stakeholders' satisfaction in relation with these three vertexes. Almost all studies related to the PDH issues have been conducted to address the suitable responds for the first aspect. However, as mentioned in the research background section, few studies have considered all related factors and interconnections - in other words, integration of these three vertexes. Indeed, previous researches normally embraced few indicators among those relevant while to assess sustainability is necessary to maximize the satisfaction of the great majority of the indicators.

Table 4.2. Studies in the area of PDH sustainability

Author	Paper Title	Year of publication	Journal title
Berke et al.	Recovery after Disaster: Achieving Sustainable Development, Mitigation and Equity	1993	Disasters
El-Masri and Graham	Natural disaster, mitigation and sustainability: the case of developing countries	2002	International Planning Studies
Shaw and Goda	From Disaster to Sustainable Civil Society: The Kobe Experience	2004	Disasters
Limoncu and Celebioglu	Post-disaster sustainable housing system in Turkey	2006	Obtenida el
Félix et al.	Guidelines to improve sustainability and cultural integration of temporary housing units	2013	i-Rec conference
El-Anwar et al.	Optimizing large-scale temporary housing arrangements after natural disasters	2009	Computing in Civil Engineering
Afify et al.	Temporary Houses from Emergency to Sustainability	2016	Proceedings of International Conference
Atmaca, and Atmac.	Comparative life cycle energy and cost analysis of post-disaster temporary housings	2016	Applied Energy

Additionally, a problem, which happens for both approaches, is different characteristics of diverse areas since: (1) no global sustainability measure exist sustainability, and (2) these could completely vary according to diversity of feature, requirements, limitations, potentials, and properties. To this end, in order to guarantee the sustainability of PDH, is essential to apply models able to handle also both stages. These approaches should have enough adaptability for dealing with limitations, such as diversity of local requirements; in other words, customizable and flexible models are necessary.

4.3.2. Importance of integrating the sustainability

Sustainability of PDH should be addressed in terms of two views: (1) integration of building industry and, (2) natural disaster conditions. On the one hand, negative impacts and requirements of building sector an how this is affected by natural hazards is an aspect of paramount importance when dealing with PDH. Natural hazards have always occurred and will do it again with different characteristics according to the climate change; these, as consequence, having an impact on economic, social and environmental aspects. Meanwhile, in order to prevent societies from natural disasters impacts is required to achieve the complete society resiliency, which is still far to be reached. In this regard, according to build back better concepts (Birkmann et al. 2010; Kennedy et al. 2008; Schneider 2012; Steinberg 2007), if PDH is provided based on sustainability concept, this accommodations will be resistant to future natural disasters. Therefore, it should be emphasized that a suitable way to achieve resiliency is sustainability. Contrarily, the frequently used temporary house units, meant to reside DP aftermath of natural disasters, are rather an unsustainable solution.

This unsustainability happens due to shortfalls in pre-disaster planning, providing in short time under emergency pressures, such as DP´s needs, political, climate conditions, etc. On the other hand, huge amount of DP´s needs for residing leads to operate building industry, which is one of the main energy and resources consumers and generators of solid waste. Thus, the combination of these factors compels decision-makers to focus more on this issue for next recovery programs.

4.4. Requirements

According to (Da Silva 2010; Hayles 2010; Limoncu & Celebioglu 2006), the following factors must be considered during the PDH management in order to guarantee sustainability: (1) suitable housing, (2) community participations, (3) neighbourhoods, (4) culture acceptance, (5) local resources (organized into *hard* and *soft* by (Lizarraldeet al. 2009)), (6) fit to climate conditions, and so on . Therefore, it could be concluded that sustainable PDH is a process that meets optimized integration of three main vertexes of sustainability concept (see Fig. 4.2): (1) minimize economic, (2) maximize social, and (3) minimize environmental impacts, based on local conditions.

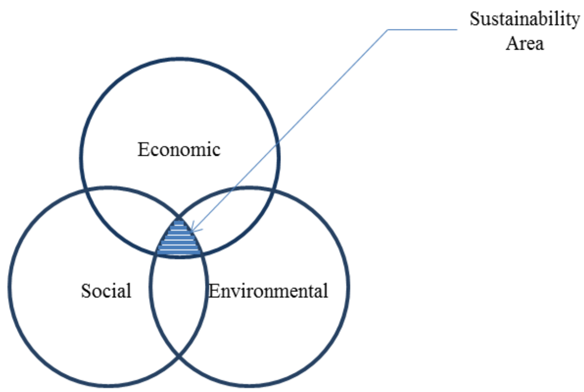

Fig. 4.2. Main requirements of PDH sustainability

These requirements embrace other specific indicators and sub-indicators for PDH; these can be organized as presented in Table 4.3. These aspects should be oriented to achieve high satisfaction level of all stakeholders. However, as local conditions and scales vary from an area to another area (United Nations Disaster Relief Organization (UNDRO) 1982), previous recovery programs should be adjusted to each new case.

These defined factors must be considered during whole life cycle of buildings, including planning, construction/provision, operation, and second life. The operation phase of PDH often is assumed as five years (Johnson 2007a). Thus, it is necessary to assess all factors from planning till reusability or demolitions of the first phase as well as for the second life.

4.5.Limitations and barriers

The limitations of PDH sustainability can be organized into two diverse areas: (1) *research limitation* on shortfalls in information especially for sustainability of PDH and explicit technical data about previous cases, and (2) *operational barriers* to achieve sustainable PDH. The operational limitations and impediments of PDH could be dealing with: (1) characteristics of recovery program and (2) establishing a universal sustainability strategy.

Table 4.3. General requirements of PDH sustainability

Requirements	Definition
Economic	This takes into account all expenses associated to PDH, from planning until first and second end life of PDH, and include: (1) pre-construction/provision phase (preparation in general); (2) construction/provision, which embraces all expenditure that is required for providing PDH; (3) operation, including all essential expenses during using PDH by DP, such as maintenance cost, and (4) second life, which can be all cost regarding to storage or to transformation from TH to another function.
Social	This requirement considers all PDH characteristics that have social impacts on who is involved in the recovery program, in whole life cycle of PDH. Thus, social indicators, such as physical and psychological health, welfare, etc., are assessed, including influential and affected groups, such as DP, neighbours, operators, etc.
Environmental	This assesses all aspects which have effect on environment due to PDH. This requirement also must be considered for all phases from beginning until end of PDH. In this regard, several factors, such as resources consumption, destructive gas emissions, waste materials, and pollutions, have to be considered for all process are related to PDH.

The limitation factor due to the characteristics of recovery program are: (1) short time for making decisions and operating, especially if there is no pre-disaster planning. However, as a pre-planning for future recovery program is based on uncertain information about the natural hazard intensity, amount of damage, this is required to modified; (2) numerous stakeholders are involved in PDH; (3) determination of factors' priorities; (4) excessive needs of PDH sometimes led to provide accommodation without considering somehow all aspects; (5) taking excessive time for assessing all factors and decision-making process; (6) lack of coordination between different parties; (7) lack of awareness about real requirements and local conditions; (8) deficiency of local sustainability and feasibility guidelines; (9) shortfall in resources and necessities; (10) climate conditions; (11) secondary hazards; (12) political situation; etc.

Furthermore, to deal with PDH, it is not possible to apply the same strategy for diverse areas with different characteristics. This fact makes limitations for decision-making process due to shortfalls in existent approaches as a sample. According to (Johnson 2007a; UNDRO 1982), each area requires particular strategies because of diverse local living standards and potentials. Moreover, each society has specific concerns and requirements that could differ from the others. In this regard, it could be pointed out that consideration of same recovery program and sustainability aspects for rural and urban areas is one of the major restrictions to achieve sustainable solutions.

4.6. Differences of urban and rural areas

The recovery issues in rural and urban areas are quite diverse (Comerio 1997) and these should be established individually. However, TH program of an urban area and a rural area can similar and based on local characteristics and similarities of both. According to International Federation of Red Cross and Red Crescent Societies (2010), urban areas should be assess individually due to their diverse characteristics, homes and other buildings, population concentrations, transportation infrastructure and industries.

Johnson (2002) stated the culture factor is more important in the rural areas, where people have different belongings and requirements compared to the urban areas. UNDRO (1982) also stated DP of the rural areas and developing counties is more self-reliant in terms of providing TH and use more indigenous materials. Moreover, urban areas experience other problems: (1) land scarcity; (2) land price and, (3) ratio of residences to residents. In this concern, the challenges of tenants' recovery housing in urban area were organized by Tafti & Tomlinson (2013) as: availability, delivery time, and tenants' desires.

Furthermore, Blaikie et al. (2014) stated one of the major factors in increasing of vulnerability is urbanization, especially of low-income people living in slums. In this regard, the growth in slum dwellers around urban areas and informal settlements (highly vulnerable in developing countries (Johnson et al. 2006)), should be considered a feature of urban areas prone to natural disaster. Contrarily, this problem is of much more minor relevance in rural areas. The slums dwelling is of paramount importance to solve: (1) unsafe housing for dwellers and (2) imprecise census statistics for recovery programs by decision-makers. In general, differences of urban and rural areas in PDH point of view can be listed as: (1) building technology, (2) abilities of DP, (3) concerns of DP, and (4) building construction cost.

4.7. Discussions

The sustainability of PDH is multifaceted problem that must be assessed in detail by considering all vertexes. In this regard, it should be emphasized that indigenous material and technologies are not always the most suitable alternative. However, these technologies could obtain high sustainability index in some cases because of high satisfaction values for some indicators. For instance, the indigenous technologies lead to maximize satisfaction values of some factors, such as comfort, climate conditions, cultural acceptance, and so on. Nevertheless, current situation of affected areas could have considerable impacts on theses satisfactions values. As an example, Steinberg (2007) stated that prefabricated housing for PDH of Indonesia aftermath of the earthquake and tsunami in 2004 could be more suitable compared to traditional housing, such as semi-permanent housing, in terms of housing quality and resistance to earthquake.

On the contrary, (Hayles 2010) declared indigenous technologies are more sustainable compared to others because these formed based on the local cultures and potentials, such as material availability and skilled labours. Moreover, this researcher declared that the buildings constructed with indigenous materials (timber, bamboo, among other) could be more flexible. Although this believe is completely correct and can achieve sustainable goals for several areas, this is not applicable for all cases, especially for urban areas.

A prominent example of using indigenous materials as most sustainable one is Arg-e-Bam (Bam Citadel). This complex had been constructed approximately 2500 years ago in Iran (Fallahi A. 2007). Arg-e-Bam is the largest adobe complex in the world (Nakamura et al. 2005) and was constructed with clay, mud brick, straw and trunks of palm (Manafpour 2008). This complex has been extensively damaged in the wake of the Bam earthquake in 2003. The Arg-e-Bam could stand during these centuries as the sustainable construction with indigenous materials. This fact demonstrates that local technologies and materials are not only factors of sustainability. For instance, other influential factors, such disaster types and intensity, can have considerable impacts on choosing a sustainable PDH. Therefore, this constant changing climate conditions and natural hazard (Banholzer et al. 2014; Van

Aalst, 2006) should be considered in PDH programs in order to minimize the negative impacts.

Another important issue of PDH that must be contemplated are those prejudices in the sustainability and suitability of TH alternatives. For instance, most researchers have admired core housing because of minimum resource consumption, emissions, and transformation time, beside other positive characteristics. However, this approach cannot be applied in urban areas with high densities. In this regard, rental units, which are well-known in terms low-consuming resources and quick availability, can achieve high satisfaction values for some indicators. However, these could obtain low values of other indicators, such as distance from pre-disaster community. Additionally, regardless of rental units availability, the rental payments should be compared with other strategies.

On other hand, THUs, as one of remained applicable options, have been used in urban areas quite often. THUs were finally demolished or stored; this leading to waste resources, expenses, and pollution. Nevertheless, these units could obtain acceptable rank in terms of other factors: quality, for instance. The high social quality of these units could also cause the long-term occupancy, becoming a permanent housing. In this sense, if THUs are considered and designed for long-term use, these unites could be ranked as sustainable alternative. Indeed, sustainability of these units could be achieved when there is a plan for whole life cycle by utilizing complete units or components for second functions. Decision-makers are forced to use this approaches in many occasions. For instance, in the wake of hurricane Katrina, there was a possibility for residing DP in rental accommodations, these were spread in 48 states (McCarthy 2008); however, this alternative was not possible for the Bam recovery program because the DP refused to leave their properties and move to the outskirt of city. From these experiences – and others –, it could be concluded that instead of completely rejecting a strategy, it is necessary to consider adjustment of local conditions and TH features. In this regard, each type of PDH could be sustainable based on local conditions and requirements.

To this end, related indicators and sub-indicators of the three vertexes (economic, social, and environmental) of PDH is required to be identified in order to deal with this issue, including diverse factors with antithetical impacts. Additionally, the limitations and impediments are required to be assessed based on capacity and potentials of affected areas.

Furthermore, it is necessary to consider these factors' priorities that are derived from particular concerns and requirements of affected areas. Meanwhile, to achieve this goal is required to assess local potentials and limitations from every point of view. Furthermore, beside constant conventional limitations, some of the mentioned factors to address sustainability of PDH could become as limitations to achieve suitable outcomes, such as community participation.

A common approach to determine factors' priorities is weighting system, which could be obtained by several methods. Regardless of human error, a most suitable weighting system is based on contribution of all stakeholders in the weighting process. Because, this approach creates an opportunity to consider PDH by all beneficiaries and experts to avoid remaining non-considered or neglected factors. As this contribution is based on bottom-up approach, beneficiaries' satisfactions usually become high. Additionally, a sometimes problem of interaction between local authorities and international organizations that results underused and low interest PDH assistance, happens due to miscalculation of factors' priorities by these non-local (outside) groups. In this regard, some researchers, such as (Fayazi & Lizarralde 2013), indicate that PDH, which are provided by non-locals, lead to high investment and low benefits (efficiency). Thus, accurately determination of indicators' priorities based on realities could play important role in PDH sustainability.

Thus, for solving complex problems, including intertwined factors and interconnections, a model is required that could adjust the priorities of this factors based on local concerns, requirements, limitations, impediments, and potentials. To this end, this study tried to provide a guideline for decision-makers with regard to unsuitability of unique strategy for all recovery programs by presenting schemes. Additionally, decision-making methods that could overcome complex issues is required to apply in order to arrive at sustainability solutions and decreasing human errors. In other words, although the qualitative analyse is essential to define and explain factors, in order to quantify (measure) sustainability index needs to apply designed models.

4.8. Conclusions and recommendations

A platform for decision-makers to deal with PDH sustainability by assessing literature review and presenting definition, requirement, and limitations has been presented in this research. Although it is not possible to define a unique strategy in this area, the outcomes of this research represents an opportunity for emergency managers to make decisions in the format of sustainability framework by explanation of problem's specifications.

The results obtained allow confirming that the different type of TH could be sustainable provided all factors are considered from very beginning stages of planning phase until end life of alternatives. In this regard, it should be emphasized that decision-makers are often forced to choose alternatives outside the scope of sustainability because there is a unique option. Nevertheless, in order to deal with this case a less-negative impact alternative could be chosen.

Additionally, as sustainability index can vary for different areas based on diversity of features, properties, and concerns, it is possible a sustainable alternative for a specific case cannot satisfy by no means (in no way) stakeholders of another case. In other words, sustainability completely is a local issue however, local technologies and indigenous materials always cannot be a most suitable results. Although, in many cases this belief comes true, this fact sometimes is in conflict with build back better concept.

Consequently, in order to evaluate sustainability of PDH is required to assess all essentials in detail like consideration of normal buildings sustainability. Furthermore, it should be added that to achieve resiliency is necessary to arrive sustainable solutions for PDH. Therefore, future studies could focus more on sustainability of PDH to achieve resilient society, beside advantages of sustainable strategy for recovery programs.

To this end, in order to achieve the sustainable alternatives for PDH the following aspects are suggested to be considered:

- To erect new layout of residential complexes, diverse engineers and experts should be involved from the early beginning until final phases. PDH should be formed by all of these professionals, beside emergency managers.
- In order to achieve suitable results is of paramount importance distinguishing between the urban and rural areas. Furthermore, the integration of all indicators involved in PDH should be considered by assuming the local conditions for each case.

- Some parts of PDH sustainability issue have been formed based on myths and prejudices that must be identified with pinpoint accuracy in order to realize truths, as some studies have already done. However, these beliefs are certainly derived from some facts; these facts could be inapplicable for other cases.

Chapter 5

Multi-criteria Decision-Making Methods for Assessing Post-Disaster Temporary Housing Sustainability

5.1. Introduction

Regardless of the prosperity level of populated areas, almost all affected areas are struggling with post-disaster housing (PDH) aftermath of natural disasters. In these areas TH is the first priority phase for the government (Hidayat 2010) because TH offers security and safety to Displaced People (DP) so they can return the pre-disaster conditions (Collins et al. 2010; Johnson 2007a). However, most Temporary Housing Units (THUs) that have been used for previous recovery programs are rejected by most experts (Johnson 2009). In general, THUs usually do not satisfy all stakeholders due to numerous weaknesses. According to numerous experts (Barakat 2003; Chandler 2007; El-Anwar et al. 2009; Hadafi & Fallahi 2010; Johnson 2002; Coffey & Trigunarsyah 2012), these units have had economic, social, and environmental problems.

According to Lizarralde & Davidson (2006), PDH strategies often fail to address the DP expectations. In this regard, Simon (1996) stated that dealing with complex emergency situations cannot rely only on decision-makers due to the bounded rationality (cited by (Kapucu & Garayev 2011)). Additionally, decision-making processes are usually implemented after natural disasters under high pressure and stressful conditions in extremely tight timeframes. Meanwhile, it is necessary to consider long-term planning (Kennedy et al. 2008) and all stakeholders' participation in decision-making to achieve suitable outcomes. Furthermore, Davidson (2009) stated that even for building construction in normal situations it is necessary to consider stakeholders' characteristics, such as culture in order to achieve appropriate organizational forms. Additionally, it should be emphasized that the organizational strategy has great impact on the supervisors' roles, which is one of the key issues for PDA provision (Gharaati & Davidson 2008).

Additionally, according to United Nations Disaster Relief Organization (UNDRO) (1982), each affected area has individual conditions that lead to choose its particular strategy. Furthermore, different natural disasters have diverse impacts (Lindell & Prater 2003), which need to be considered individually. Therefore, decision-makers need to choose a suitable strategy to deal with PDH issue, which embraces intertwined interior and exterior factors that could have antithetical impacts on each particular case (Hall, 1962) (cited by (Johnson 2007a)). Thus, if decision-makers do not apply previous recovery strategies there is no platform for decision-making process. Moreover, when previous strategies are used there is no guarantee to achieve similar outcomes. In this regard, Kapucu & Garayev (2011) stated that traditional decision-making approaches cannot be used in emergencies, which need flexible tools. Therefore, it is necessary to have a model that could cover human errors and consider the correspondences and interconnections between previous cases and new cases.

To this end, the main **objective** of this chapter is to present a suitable decision-making tool to deal with PDHs by defining the features of decision-making of PDH and considering the tools, which have been applied in this case. Within this PDHs complicated issue this fourth chapter focuses on TH. Therefore, this study defines requirements (characteristics) of decision-making of recovery programs. Then, an appropriate tool, which embraces exclusively the main TH sustainability requirements, is defined Additionally, the previously mentioned five case studies are analysed in order to determine emergency management requirements, outcomes, and sustainability indicators. In this sense, this research aims to solve the following two questions:

- Which are the main requirements for the decision-making process to deal with PDH?
- Which is the most suitable method to assess the PDH sustainability focusing on the aforementioned main requirements?

5.2. Research Background

This study analyses decision-making models that have been applied to assess PDH suitability. Although most academic studies about PDH are new, the number of these studies which are outstanding is high. However, few studies have considered the sustainability and optimization of PDH (El-Anwar et al. 2009; Yi & Yang 2014). Additionally, compared to the other considered issues, there are few studies that have been conducted focusing on decision-making tools for PDH issues. These previous studies that have developed decision-making methods are the following: a generic decision model for PDH (Peng et al. 2014), a decision process for secure site location (Hale & Moberg, 2005), selection of fixed seismic shelters by the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) (Chua & Su 2012), considering earthquake evacuation capacity by Analytic Hierarchy Process (AHP) (Ma at al. 2011), settlement suitability by geographical information system (GIS) (Alparslan at al. 2008), earthquake refugee shelters by combination of GIS and entropy methods (Li et al. 2013), analysing the sustainable site selection and decision-making methods by GIS and multi-attribute decision making (MADM) (Omidvar et al. 2013), urban shelter locations based on covering models (Wei et al. 2012), selecting suitable site location of TH by the MIVES (Hosseini et al. 2016b), TH technology aftermath of Bam earthquake by the MIVES (Hosseini et al. 2016a), hierarchical location models for earthquake-shelter planning (Chen et al. 2013), selecting site of temporary sheltering using Fuzzy algorithms (Nojavan & Omidvar 2013), optimizing PDH allocation (El-Anwar et al. 2009a), and optimizing TH assignments to minimize displacement distance (El-Anwar & Chen 2012).

5.2.1. Decision-making process for post-disaster housing

Decision-making process of post-disaster housing could be accomplished mainly by two approaches: (1) choosing suitable options among limited alternatives. For instance, decision-making models can be applied to find out an appropriate approach of TH site location among camp and yard of DP´s pre-disaster housing. For another example, choosing a suitable site location of THUs between initial chosen site (see (Hosseini et al. 2016b) and (Omidvar et al. 2013)); and (2) determining suitable possible alternatives without having initial alternatives. For instance, a model is used for choosing a proper settlement by considering all areas (see (Alparslan et al. 2008)). Indeed, the main difference of these first and second approaches is related to the number of available alternatives. In the first approach the number of alternative is limited while in the second category there are numerous alternatives.

5.3. Case studies

This research analyses five different cases from the management point of view. These cases are the following: (1) earthquake in Turkey (1999), (2) earthquake in Iran (2003), (3) earthquake in Italy (2009), (4) earthquake and tsunami in Indonesia (2004) and (5) hurricane and flood in USA (2005). These cases are shown in Table 5.1. The assessment of these cases demonstrates that decision-making processes can be one of the elements that has major impacts on success or failure of PDH programs. Additionally, different indicators with diverse interactions were involved in the studied cases. Furthermore, the importance of indicators can vary from case to case based on natural disasters types and scales, local characteristics, and resiliency. In line with this, it is difficult to guarantee that the PDH program that has been useful for one case will be suitable for another case with different conditions. Thus, in the aftermath of a natural disaster, authorities are confronted with a complicated decision-making process in order to provide each disaster best PDH, which includes different choices and stages.

The recovery program of five cases varied based on the local characteristics and resiliency. All these cases almost struggled with recovery program and consequently, faced individual difficulties, as shown in Table 5.1. Moreover, the main common problems of the five cases regardless of these cases' differences are the following: (1) late delivery, (2) mismatching with local culture, (3) inappropriate organization strategy and (4) strategy deficiency in dealing with tenants.

Table 5.1. Information of the five case studies

Case study	Hazard	Intensity	Problem Issue	Reference
Turkey 1999	Earthquake	Mw=7.4 and Mw=7.2	(a) Site location, (b) Long-term plan, (c) Facilities, and (d) Environment	(Arslan & Unlu 2006; Tas et al. 2007; Johnson 2007b ; Sphere Project 2004)
Iran 2003	Earthquake	Ms=6.5	(a) Site location, (b) Material, and (c) Emigrant	(Amini Hosseini et al. 2013; Ghafory-Ashtiany & Hosseini 2008)
Indonesia 2004	Earthquake Tsunami	Mw=9.2	(a) complexity, (b) Site location, and (c) quality	(Da Silva 2010; Doocy et al. 2006; Steinberg 2007)
USA 2005	Hurricane Flood	Category 3	(a) dispersal of DP, (b) utilities, and (c) Environment	(Chandler 2007; McCarthy 2008; Nigg et al. 2006)
Italy 2009	Earthquake	Mw=6.3	(a) Site Location, (b) delay in reconstruction, and (c) cost	(Alexander 2010; Özerdem & Rufini 2013; Rossetto et al. 2014)

5.3.1. Analysis of cases

Aftermath of two earthquakes in Turkey in 1999, the economic loss caused by the amount of buildings was around $5 billion (Erdik 2000). The Turkey recovery program utilized THUs because of DP numbers and the intolerable climate conditions. Because of these climate conditions the Turkish government was forced to erect THUs for DP. Nevertheless, THUs have been rejected by most researchers due to its negative impacts.. On the contrary, decision-makers of Indonesia recovery program due to the earthquake and tsunami in 2004, which caused approximately 220,000 deaths and 10,000 injured people (Steinberg 2007), decided to apply a self-built or community-built program by considering the local potentials and DP characteristics. Indeed, a top-down approach has been applied for the Turkey case and bottom-up approach for the Indonesia case because of each recovery program organization approach (Dikmen et al. 2012). Although the bottom-up approach considers all beneficiaries' requirements by empowering DP (Dikmen et al. 2012), this approach has proven to be more successful in terms of adaptation to culture, local skills, and climate conditions (El-Anwar et al. 2009; Johnson 2007b). Additionally, regardless of recovery program approaches, the recovery program of Aceh, Indonesia, led to long delivery, higher expenses, and poor quality because the strategy was changed several times (Da Silva 2010).

According to (Fois & Forino 2014; Ghafory-Ashtiany & Hosseini 2008; Johnson 2007b), aftermath of the natural disasters in Turkey, 1999, Bam, 2003, and Italy, 2009, some of THUs were vacant because of the DP rejections. These situations, which occurred due to unsuitable decision-making methods for covering all requirements and indicators, led to waste a lot of time and investment, moreover, DP' dissatisfaction. For instance, Johnson (2007b) stated that from THUs, which had been provided after the earthquakes in Turkey of 1999, 2.5 per cent were vacant. On the other hand, shortfalls in decision-making by authorities can forced DP to provide unofficial THU as a self-built accommodation such as, the Colombian recovery program after the Armenia earthquake, 1999 (Johnson et al. 2006). Therefore, weaknesses of decision-making process somehow results in unacceptable and sometimes unexpected outcomes.

Alexander (2004) stated that without the consideration of the magnitude of losses, the local financial statue affected area has considerable impacts on its resilience to disaster. In this regard, the assessment of the different aforementioned cases completely demonstrates how diverse local financials impact on final decision-making. Furthermore, other local potentials such as building construction industry with different technology and speed also lead to diverse decisions. For instance, the local potentials such as building construction industry of Italy in the wake of L'Aquila earthquake, which led to 308 deaths and 67,500 DP (Alexander 2010), were able to provide these accommodations with great speed based on the required standards. However, the recovery strategy aftermath of L'Aquila earthquake designed by the government had sustainability problems (Fois & Forino 2014). Additionally, different local conditions, such as climate condition, forces authorities to choose individual PDH strategy. As an example, the Turkey recovery program which utilized THUs because of DP numbers and the intolerable climate conditions. In this sense, the Indonesian decision-makers in 2004, had to change the initial strategy because the tents declined under the tropical conditions (Da Silva 2010; Steinberg 2007).

Additionally, some people migrant to the affected area after Turkey, 1999, and Bam, 2003, earthquakes from other areas. Meanwhile, the trailers of the Katrina recovery program were not a perfect solution for returning DP (McCarthy et al. 2006) despite the fact that the trailers quality can be considerably higher than THUs of another case. Furthermore, in the wake of the Hurricane Katrina, which caused 570 deaths, $40-50 billion economic lost (Kates et al. 2006), and 770,000 DP (Weiss 2006), emergency managers were aware about the hurricane. This awareness did not exist for authorities of the Bam earthquake, which remained more than 90% of destroyed buildings in the urban areas (Fayazi & Lizarralde 2013). Meanwhile, the decision-makers had the ability to erect tents and THUs on the yard of DP´s pre-disaster housing. This possibility was not applicable to the recovery program aftermath of the Hurricane Katrina because according to Chandler (2007), area was pumped dry by the September 20.

5.4. Findings

The assessment of these five cases demonstrates that there are some similarities and dissimilarities between different recovery programs. Additionally, all considered decision-making process aspects of the study cases could be organized in the three factors shown in Fig. 5.1. Indeed, final decisions are derived from these three main vertexes. *Properties* group, which embraces all material and immaterial things that have formed characteristics of the affected area, such as financial powers, technology, facilities, features of population, climate conditions, etc.

In general, the Properties factor can be broken down into four components: belongings, attributes, environmental, and technical aspects. The *Belongings* category considers substantial components of the area, such as buildings including public and private accommodations and services, utilities, facilities, infrastructures, available areas, etc. and their qualities. The *Attributes* category takes into account the wide immaterial complex of economic, social, and political characteristics in the area based on numerous factors, such as life standards, livelihood, welfares, cooperative spirit, abilities, etc. The *Environmental* aspect embraces climate conditions, geographical aspects, and potential threats. The

Technical aspect considers local abilities to deal with providing temporary and permanent housing related to technical capacities, including: construction methods, skilled/expert human resources, material availability, construction firms and companies, reuse systems, transportation quality, etc.

The *Requirements* vertex, which consists of many diverse physical and psychological aspects, takes into account all essentials for returning the post-disaster situations to the pre-disaster or better situations, especially in terms of DP. The last vertex is *Limitations* group, which embraces all factors that cause difficulties and restrict to arrive to the solutions and achieve suitable requirements, such as timing, number of DP, natural hazard types and effects, etc. Some of the properties could become limitations such as climate conditions, especially when natural hazard happens during a season with unsuitable climate conditions.

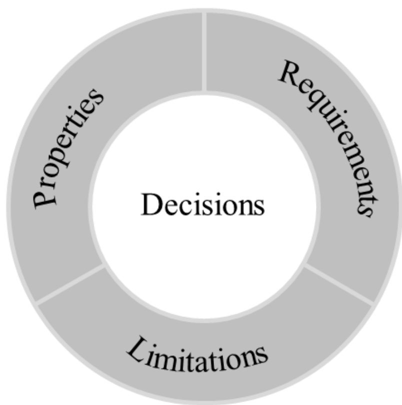

Fig. 5.1. Three main factors of decision-making process

Therefore, PDH strategy is the complicated multifaceted process includes many different factors with diverse interconnections and sometimes-antithetical impacts on different cases. A decision-making tool needs to be a comprehensive method and it should be customizable. Decision-makers should be able to improve this tool by determining priorities of indicators or/and adding new specific indicators. This addition would be based on individual characteristics of each case, which embraces features of population and area.

5.5. Required characteristics for post-disaster natural decision-making models

In general, to deal with recovery programs in the aftermath of natural disasters decision-makers need to determine specific characteristics of these programs in order to design or choose a suitable decision-making model. Therefore, according to the considered cases and (Hayles 2010; Pearce 2003; Von Meding et al. 2016; Zavadskas et al. 2016), the characteristics of PDH decision-making processes, especially TH processes, are the following: (1) many diverse beneficiaries with different expertise are involved in decision-making process, (2) numbers of organizations participate in parallel, (3) there are distinct short- and long-terms requirements, (4) its indicators have diverse interconnections with linear and non-linear functions, (5) a individual strategy for each recovery program is needed and (6) although it is essential to have a pre-plan for dealing with natural disasters there is uncertain initial information and final requirements are determined in the post-disaster period.

Therefore, decision-making models that are applied to determine suitable PDH and TH alternatives based on the individual characteristics of each case should be: (1) easy understandable, (2) customizable, (3) quick enforceable, (4) able to satisfy all beneficiaries' concerns (5) able to consider diverse quantitative or qualitative indicators with different units, (6) able to incorporate the utility theory and (7) flexible to incorporate changes.

5.5.1. Considering suitability of models and tools

Decision-making techniques that have been applied for PDH assessments in previous research projects are shown in Table 5.2. This fourth chapter assesses these methods based on the required characteristics of decision-making methods to select the most suitable one of these methods. However, Ozernoy (1989) stated that choosing a suitable MCDM is a MCDM problem that needs to apply a decision-making process. In this regard, Zanakis et al. (1998) stated that it is very difficult to answer this question: which method is more suitable for a specific problem? (Zanakis et al. 1998). Nevertheless, this present study determines the best Decision-Making for the study cases taking into account the strengths and weaknesses of the assessed tools.

Table 5.2. Main characteristics of the assessed decision-making tools

Method	Main Characteristic	Reference
AHP	experts' knowledge, priority theory, hierarchical structure analysis, flexible, ranking irregularities, pairwise comparison, rank reversal	(Aruldoss et al. 2013; Triantaphyllou 2013; Velasquez & Hester 2013)
TOPSIS	tendency of monotonically increasing or decreasing utility, shortest distance from the positive ideal and farthest from negative one, alternative ranking method, widely applied method, difficult to weight	(Aruldoss et al. 2013; Stanujkic et al. 2013; Triantaphyllou 2013; Velasquez & Hester 2013)
MIVES	value function based on the utility theory, experts' knowledge, alternative ranking and selection method, sustainability assessment tool, easy to understand, a combination of techniques, requirements tree	(Cuadrado et al. 2015a, b; del Caño A. 2012; del Caño et al. 2015)
ELECTRE	alternative selection method, time consuming, outranking relations, coordination indices, alternatives pairwise comparison, different outputs from other methods	(Aruldoss et al. 2013; Triantaphyllou 2013)
SAW	almost simplest and oldest method, popular to practitioners, intuitive, sometimes illogical results	(Stanujkic et al. 2013; Triantaphyllou 2013; Velasquez & Hester 2013)
Fuzzy Theory	widely applied method, ability of imprecise input and insufficient information, difficult, time consuming	(Hwang & Yoon 2012; Velasquez & Hester 2013)

Almost all compensation methods could be risky for decision-making on recovery program issues because it is possible to choose an alternative with ineligible features. For instance, distance from source of danger can be one of the most important indicators for selecting site location of THUs. Thus, in order to choose the most suitable site between two alternatives, it is difficult to select which one would be better than the other when adding the assessment of numerous other important indicators as well. In this sense, the indicator-weighting system could help to avoid choosing unsuitable alternatives. Additionally, the utility theory, which is the base of MIVES method, also prevents from unsuitable solutions. Furthermore, satisfactions of stakeholders for most indicators are not based on linear functions. Thus, utility theory needs to be applied to address a suitable strategy for PDH. For example, distance from source of danger indicator cannot be assessed with a linear function by considering only distances from site alternative to source of danger. Therefore, with regard to Table 5.2 and the aforementioned PDH essentials the author concludes that all methods have advantages and disadvantages but MIVES is the most suitable method.

According to Aruldoss, et al. (2013), MCDM such as the methods presented in Table 2, can reach strong decisions for considerable complex issues involving multi criteria. These experts also state that each method has special uniqueness. In regards to their simplicity, according to Stanujkic et al. (2013), SAW is one of the simplest tools. In this sense, AHP is a simple method as well. On the other hand, most methods have the ability to deal with PDH. Additionally, the assessed methods embrace most required characteristics of decision-making techniques with different qualities, as shown in Table 5.2. Nevertheless, although all assessed tools cover all essentials, MIVES is the only method that takes into account value functions based on the utility theory. However, Hwang and Yoon (2012) indicated that it is possible to replace the simple additive weighting function of SAW method by additive utility function.

5.6. MIVES

The integrated value Model for Sustainable Assessment from the Spanish (MIVES) consists of a multi-criteria decision-making method that incorporates the concept of value function (Alarcon et al. 2011). This model considers the main sustainability requirements (economic, environmental, and social). In addition, by means of the value functions the satisfaction degree of the involved indicators, which might have different units, can be assessed. According to (Alarcon et al. 2011) and (San-Jose´ Lombera & Garrucho Aprea 2010), MIVES presents rates satisfaction on a scale from 0 to 1, where 0 indicates minimum satisfaction (Smin) and 1 indicates maximum satisfaction (Smax). MIVES was developed by three different Spanish institutions (UPC, UPV, and Labein-Tecnalia) and this work is the initial application in the field for industrial buildings (Alarcon et al. 2011).

MIVES has been used more recently to assess the sustainability and to make decisions in the fields of (1) university professors (Viñolas et al. 2009), (2) economic decisions in the Barcelona Metro Line 9 (Ormazabal et al. 2008), (3) industrial buildings (Lombera & Rojo 2010), (4) the Spanish Structural Concrete Code (Aguado et al. 2012), (5) sewerage concrete pipes (Viñolas 2011), (6) school edifices (Pons & Aguado 2012), (7) developing the probabilistic method MIVES–EHEm–Mcarlo for large and complex edifices (Alfredo del Caño 2012), (8) structural concrete columns (Pons & Fuente 2013), (9) wind-turbine supports (Fuente et al. 2014), and (10) TH (Hosseiniet al. 2016a,b).

According to MIVES, a specific tree that includes requirements, criteria, and indicators which is shown in Fig. 5.2 is developed to assess the sustainability of alternatives. The designed tree must contain minimum indicators, which are independent from each other and calculable to be assigned in formula. The MIVES tree has three different hierarchical levels. First level of tree includes the economic, environmental and social requirements, the second hierarchical level has the criteria, and the third and last level has the indicators. Unlike requirements and criteria, indicators are measurable variables to quantify each alternative site.

By determining a value function for each indicator according to MIVES equations, it is possible to quantify each attribute. According to (Alarcon et al. 2011) and (San-Jose´ Lombera & Garrucho Aprea 2010), to determine the satisfaction value, there are four stages as follow: (1) determine the tendency (increase or decrease) of the value function, (2) determine the points in order to find minimum (Smin, value 0) and maximum (Smax, value 1) satisfaction, (3) determine the shape of the value function (linear, concave, convex, S-shaped) and (4) determine the mathematical expression of the value function.

According to (Alarcon et al. 2011), in a concave curve when the value of the indicator starts to increase, satisfaction rapidly increases. A concave curve is chosen when most alternatives are close to the minimum satisfaction, as shown in Fig. 5.3. In a convex function, when the value of the indicator starts to increase, the satisfaction slightly increases. Unlike the previous case, the convex function is selected when approaching the maximum satisfaction point is more important than moving away from the minimum satisfaction point. In this last case, most alternatives are close to the maximum satisfaction point, as shown in Fig. 5.3.

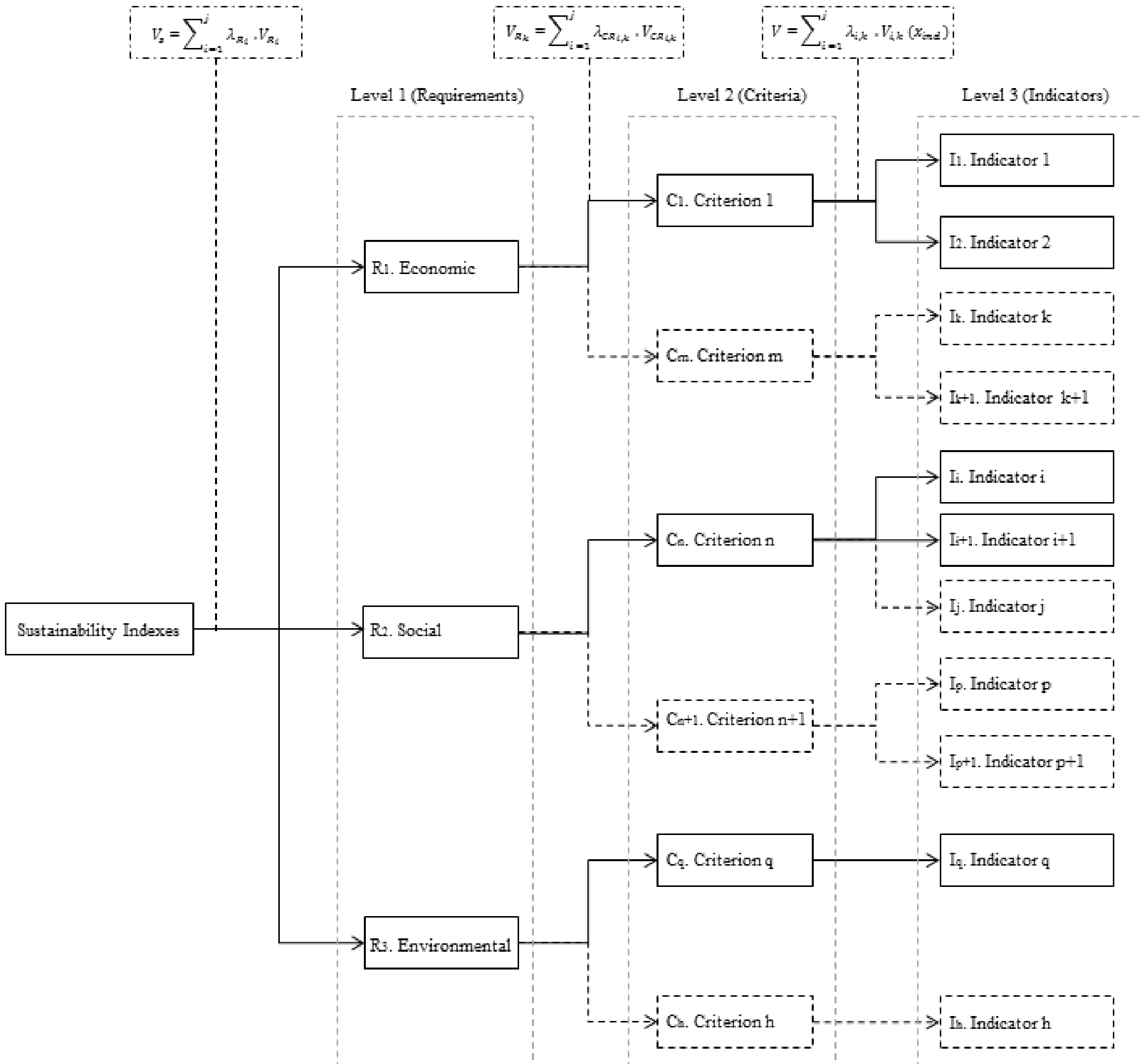

Fig. 5.2. MIVES tree including requirements, criteria, and indicators

A linear function presents a steady increase in satisfaction. An S-shaped function is a combination of concave and convex functions, as shown in Fig. 5.3. In an S-shaped function, a considerable increase in satisfaction is obtained in the middle range of values. This S-shape is chosen when most alternatives are centralized into a middle range, as shown in Fig. 5.3.

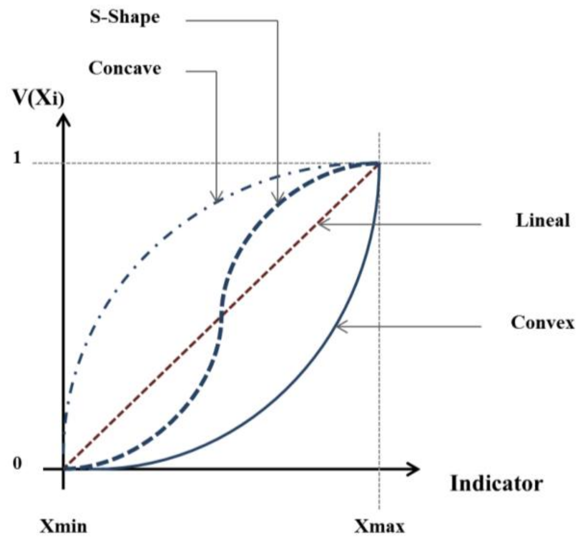

Fig. 5.3. Value function types

The parameters, tendency and shape of the value function for each indicator are determined from international guidelines, scientific literature, National Building Regulations, and the background of experts that participated in the seminars. In the next step, the value function is obtained based upon the general exponential in MIVES Eq. (5.1).

$$V_i = A + B.\left[1 - e^{-k_i \cdot \left(\frac{|X_{ind} - X_{min}|}{C_i}\right)^{P_i}}\right] \quad (5.1)$$

A : The response value X_{min} (indicator's abscissa), Generally $A = 0$

X_{ind} : The considered indicator abscissa which generates a value V_i

P_i : A shape factor that determines if the curve is concave or convex; or is linear or shaped as a ''S''

C_i : Factor that establishes, in curves with Pi > 1, abscissa's value for the inflexion point.

K_i : Factor that defines the response value to C_i

B : The factor that prevents the function from getting out of the range (0.00, 1.00), is obtained by Eq. (5.2).

The sets of indicator values ($V_i\,(x_i)$) that are between 0 and 1, according to the satisfaction range, is generated by Eq. (5.1). [1]

$$B = \left[1 - e^{k_i \cdot \left(\frac{|x_{max} - x_{min}|}{c_i}\right)^{P_i}}\right]^{-1} \tag{5.2}$$

After the assessment of indicators value for each alternative, the formula that is presented in Eq. (5.3) needs to be applied. In this equation, the indicator value ($V_i(x_i)$) has previously been determined and the weights (λ_i) are assigned to determine the sustainability value of each branch. For the multi-criteria case, the additive formula corresponding to Eq. (5.3) is applied to determine the sustainability value of each level including indicators, criteria, and requirements.

$$V = \sum \lambda_i \cdot V_i\,(x_i) \tag{5.3}$$

$V_i\,(x_i)$: The value function of each indicator and each criterion

λ_i : The weight of considered indicator or criterion

In this step, the weights of the requirements, criteria, and indicators (λ_i) are assigned by using the Analytical Hierarchy Process (AHP) based on previous studies, local characteristics, and the knowledge of the experts involved in seminars.

5.7. Discussions

MIVES creates an opportunity for decision-makers to assess different indicators with divers characteristics as do most decision-making models. However, as MIVES includes the value function concept based on the utilities theory concept, indicators' values of each alternative are obtained more accurately. Meanwhile, for most issues, especially for housing and PDH, relations between parameters and satisfaction degree of the stakeholders are not based on linear functions.

One of MIVES advantages is the consideration of indicators independently although this method is a compensation decision-making model. In order to define a MIVES model for PDH, which contains intertwined factors, decision-makers who are experts in this area are needed. These decision-makers should have the ability to define independent indicators that embrace all required aspects. In this regard, the MIVES model can be improved by considering interconnections of indicators. In this sense AHP, which is the weighting assignment system that is applied in MIVES method, makes indirect connections between indicators. Furthermore, this study suggests applying the Analytic Network Process (ANP) to use advantages of AHP and in order to strengthen the interconnections of indicators.

Additionally, as different cities have various local living standards and characteristics, the weight of indicators, criteria, and requirements would be different from one area to another (Davis 1982; Johnson 2007a). Therefore, the MIVES methodology, which can be used for different locations with diverse characteristics without being limited by the present conjuncture, has more suitability for this issue. Furthermore, this model is capable of engaging local specialist and authorities from divers departments in decision-making processes.

Indeed, in MIVES methodology, indexes weights are determined by experts during several seminars and meeting using AHP. It is an appropriate idea to use AHP method, which helps to organize the process efficiently, to reduce the model complexity and subjectivity and decrease possible disagreements between the team members (del Caño et al. 2015). To this end, the participation of all stakeholders in management processes is needed (Kapucu & Garayev 2011) Moreover, these stakeholders should have different expertise or their assignation of weights could not reach the most suitable outcomes. In this sense, MIVES uses seminars of experts to determine the weights that assist to find out suitable results and eliminate outliers.

Additionally, in MIVES weights assignation process other approaches such as the Shannon's entropy can be applied (can see (Hosseini et al. 2016b)). Furthermore, decision-makers who apply MIVES can change weights easily and quickly in order to analyse different scenarios and results (can see (Hosseini et al. 2016a, b)). In this regard, when weights of each requirements, which includes more criteria and indicators, are changed, sustainability value is changed extremely compared to change of weights of other requirements. However, the last issue happens to all decision-making models which are based on the weight assignment system.

5.8. Conclusion

This chapter present determines the suitability of several decision-making models by considering the techniques, which have been applied for previous researches, defining the essential requirements of decision-making methods for PDH, and analysing the five different case studies. The assessment of the cases with diverse characteristics in terms of financial power, social levels, and natural hazards confirms that almost all decision process had considerable problems to arrive the solutions. These conditions represent that to address a suitable PDH requires replacing any old decision process with the new decision-making model, together with the integration of the all the expertise involved in this issue. Additionally, this study finds that all the factors, which are involved in decision-making process, can be organized into the three main vertexes: properties, requirements, and limitations.

This research demonstrates that the MIVES method has more appropriate characteristic for dealing with PDH compared to the other assessed methods. In general, decision-makers could obtain suitable alternatives easily and quickly by applying MIVES in an emergency situation after natural disaster. Meanwhile, MIVES like other decision-making model has advantages and disadvantages, which need to be modified. However, MIVES has been selected as the most suitable model because of its following positive features. For decision-making process of PDA, it is necessary to select as the suitable technique with considering following aspects:

- It permits all stakeholders to participate in the decision-making process.
- Incorporates value functions based on the utility theory concept that leads to achieve more accurate results. This prevents to choose an alternative with ineligible features that are vital for all decision process, especially PDH.
- It specifies the best alternative(s), it ranks all alternatives, and it identifies the major characteristics and the appropriate area of each alternative during operation,

This study provides a platform that will be useful for future researches in order to select the best combination of the methods used for previous studies. This platform is based on the main requirements of the study cases decision processes and the features of the assessed methods in this fourth chapter.

Chapter 6

Post-disaster Temporary Housing: A Steps Scenario Strategy for Choosing Sustainable Solutions

6.1. Introduction

An average of 22.5 million people lost their home due to related disasters to climate or weather each year from 2008. Moreover, this trend is expected to magnify in the future based on increment of weather-related events and population vulnerability (Yonetani 2015). Therefore, all areas prone to natural disasters need to have a resilience program for dealing with the displaced people´s (DP´s) accommodations not only items of provision, but also with regard to the impacts of this huge TH for the years come.

TH, which should supply security and safety against climate, disease, and other possible dangers (Collins et al. 2010; Davis 1978; Félix er al. 2013), has considerable economic, social, and environmental negative impacts (Alexander 2010; Barakat 2003;

Chandler 2007; Coffey and Trigunarsyah 2012, El-Anwar et al. 2009; Hadafi and Fallahi 2010; Johnson 2002; Wei et al. 2012). The TH phase as the one of the four organized phases by Quarantelli (1995), as (1) emergency shelter, (2) temporary shelter, (3) temporary housing (TH), and (4) permanent, cannot be concealed or cancelled. Additionally, as this issue embraces several stakeholders with different requirements, and sometimes in contrasts to each other, a strategy which is chosen cannot completely convince all the beneficiaries.

The problems mentioned before can worsen when an initial chosen strategy is changed by decision-makers in order to select a more suitable one. However, the new recovery strategy can make a higher DP´s satisfaction compared to the previous one, but the process of changing strategies can be time, expenses, and energy consuming. In this case, Da Silva (2010) stated that choosing the strategy of Aceh´s recovery program for several times led to late delivery, expenses, and poor quality. Additionally, improper initial site selection of temporary housing units (THUs) after the Bam earthquake, 2003, was a reason for the rejection of THUs (Ghafory-Ashtiany and Hosseini 2008; Khazai and Hausler 2005), which compelled decision-makers to change the strategy after erecting a considerable number of TH. These situations demonstrate that the decision-makers of both cases could have chosen the most suitable strategies from beginning and by doing so, reduce the negative impacts, if the decision-makers were aware the outcomes.

Thus, the **objective** of this chapter is to present a strategy for dealing with TH selection in order to reduce negative impacts by considering concepts of sustainability and stakeholders’ satisfactions. In other words, this study aims to assist decision-makers for choosing the most suitable strategy, which brings higher beneficiaries’ satisfactions, by considering individual local conditions, and therefore, the minimum negative effects compared to other alternative strategies.

This study analyses the recovery programs of Bam, earthquake in Iran (2003) and the aftermath of the earthquake and tsunami in Aceh, Indonesia, (2004), whose decision-makers were forced to change the site selection and TH strategies. This study derives the indicators, which have influence on sustainability indexes (SI) of the alternatives, from primary and secondary sources. Finally, a model, which creates an opportunity for decision-makers to avoid choosing an unsuitable strategy based on sustainability concept (minimum economic, maximum social, and minimum environmental impacts) and steps scenario, is designed and applied for analysing the case studies.

6.2. Life cycle phases of temporary housing

The life cycle of TH can be organized into four phases: planning, provision or construction, operation, and second life, as shown in Fig. 6.1. In the planning phase, the initial form of TH is determined by decision-makers and experts to be applied after probabilistic natural hazards. However, this phase was contingent upon the natural disaster for considerable number of previous recovery cases. Indeed, alternative accommodation types and their requirements are specified. In the provision or construction phase, this usually starts after natural disasters, temporary accommodations and required facilities are prepared to be used by DP, such as organizing available accommodations, constructing units, site preparation, and so on. The operation phase starts when DP resides until leaving. However, it is possible that DP stays in TH for a long time as a permanent housing; Johnson (2007) stated this accommodation can be used five years maximum as a TH. Therefore, this phase embraces all factors during use of these accommodations as TH. The second life phase considers what happens to TH after the DP leave.

According to (Arslan and Cosgun 2008; Johnson 2009), the possible scenarios which can happen for TH, especially THUs, after DP leave are: (1) storage for potential use, such as TH for future post-disaster, and (2) reuse with two different approaches: (a) complete building and (b) component usage. In the first approach, there are three different scenarios for THUs in order to *location* (same or another location), *property condition* (THUs can be sold, rented or donated), and *function* (same or other function). In the second approach, component usage, the components of THUs can be used as main building components, raw materials, and recycled materials.

6.3. Case studies

6.3.1. Iran, 2003

In the wake of the earthquake happening in Bam on December 26th, 2003, the amount of destroyed buildings in urban area were more than 90% (Fayazi and Lizarralde 2013), moreover, some factors of the three main vertexes (local, natural hazard, and TH characteristics) of the Bam case are presented in **(Chapter 3)**. The Iranian government selected The Foundation of Islamic Republic of Iran (HFIR) and the Ministry of Defence as the responsible for TH provision. The THUs were constructed by these two organizations directly or by hired contractors. The authorities decided to apply three phases: (1) tent shelters, (2) intermediate shelters, and (3) permanent housing (Khazai and Hausler 2005). To this end, tents and NATH, consisting of prefabricated and in-situ units on camp (grouped) and yard of DP´s housing (dispersed), were applied. The Iran Red Crescent Society provided more than 50,000 tents as temporary shelter within the first day (Ghafory-Ashtiany and Hosseini 2008). For TH provision the different technologies were used, such as pre-fabricated and masonry technology on camp site or private properties.

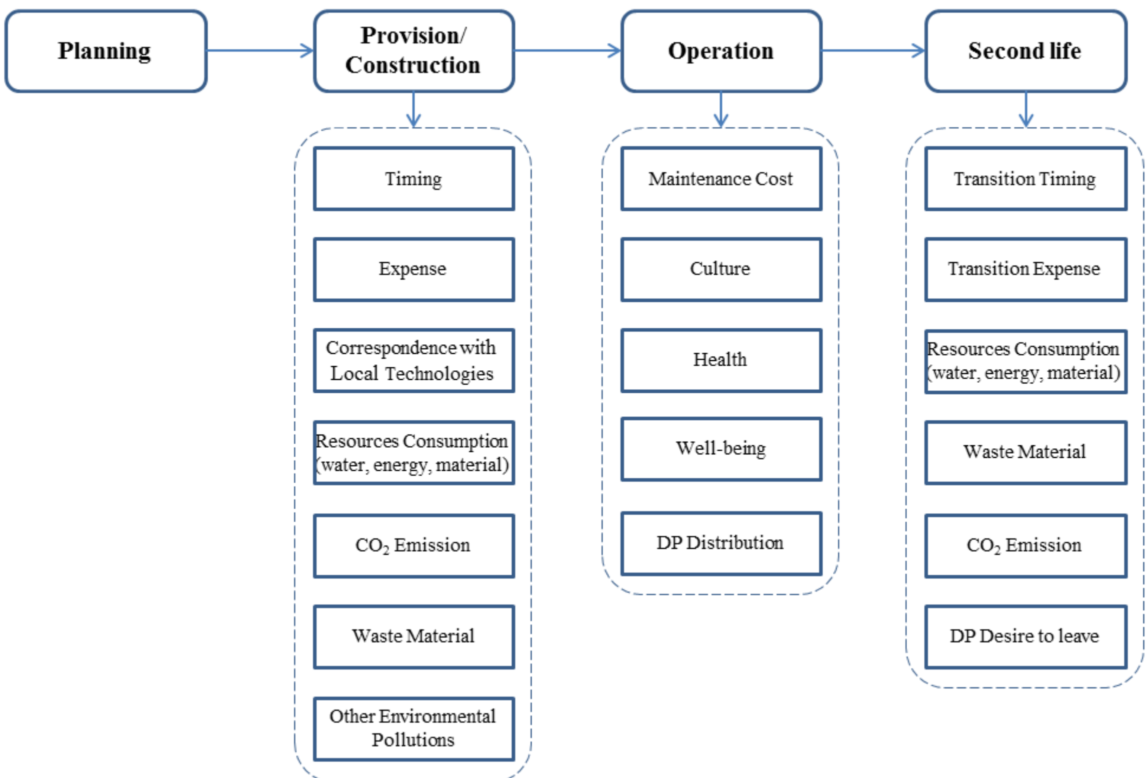

Fig. 6.1. Life cycle phases of TH from cradle to grave and associated indicators

Indeed, decision-makers were forced to change the camp site strategy into the private yard of DP because DP did not desire to use the THUs on camp site. Therefore, form 35,905 THUs, 9,005 of which were erected on camp site and 26,900 on DP´s private properties (Ghafory-Ashtiany and Hosseini 2008). According to Fayazi and Lizarralde

(2013), only those THUs, which were built with masonry materials, were used as living space after the TH phase however, all THUs on private properties became permanent.

As most natural disaster affected-areas, Bam was faced to shortage of building materials and increased prices. Therefore, many houses were not completed because the reconstruction loans were not sufficient due to increase of construction prices (Amini Hosseini et al. 2013). However, this situation happened not only for low-income homeowners, but also middle range income DP had difficulties in finishing the permanent houses (Tafti and Tomlinson 2013).

6.3.2. Indonesia, 2004

In the aftermath of the earthquake and tsunami on December 26th in Indonesia, approximately 220,000 died (Steinberg 2007). The diverse approaches that were applied in the wake of the Aceh earthquake, were the self-help system and third-parties. The most organizations involved in the Aceh recovery program firstly proposed to apply self- or community-build programmes (Da Silva 2010). At first, authorities decided to bridge between sheltering and permanent housing thus, tents and barracks were prepared for DP as a shelter and TH phase; however, this goal could not be achieved completely. According to Da Silva (2010), only less than half of considered population were accommodated in barracks after one year. Meanwhile, the Sri Lankan had a transitional shelter strategy form the beginning of the recovery program therefore; more than 100,000 temporary shelters were provided within nine months (Da Silva 2010). Therefore, the decision-makers forced to provide different types of transitional shelter to settle DP until finishing the permanent housing, and changed their initial strategy. Additionally, the tropical climate condition of Aceh was one of the main reasons for changing the initial strategies.

6.4. Suggested model

This research presents a model based on a steps scenario, which consists in a comprehensive strategy for choosing the most suitable TH, as shown in Fig. 6.2. The general strategy includes three phases: initial, intermediate, and final phase. The Initial phase takes into account availabilities and possibilities of TH provision approaches based on the three main vertexes of TH (natural hazards, local characteristics, and TH properties).

Indeed, this phase results in which TH types can be utilized with regard to local conditions. The Intermediate phase, which is the main goal of this study, considers TH types, such as rental accommodations, trailers, units, and so on, to determine the most suitable one based on the integration of the three vertexes and sustainability concepts. In this regard, all factors involved have been defined and organized to facilitate the decision-making process, and consequently maximizing the probabilities of selecting a suitable alternative. The essential information of this model phase has been derived from primary and secondary sources.

Indeed, the possible TH approaches, which have been determined by the first phase, have been ranked considering indicators related to the sustainability concepts to reduce negative impacts in this phase. Thus, each suitable TH approach, which has a less negative feature when corresponding to the three vertexes, are specified by the steps scenario. The Final phase considers the sustainability index (SI) of alternatives which have passed from the Intermediate phase. Indeed, within this phase is where most sustainable TH strategies are determined, while alternatives of each TH strategy are considered in the Final phase. For instance, rental accommodation and THUs are ranked in the Intermediate phase in terms of SI whereas alternatives of THUs, such as diverse prefabricated technologies and masonry, are assessed during the Final phase. In this sense, both the Initial and Final phases have been extensively described in the other chapters.

6.5. Steps scenarios

After a natural disaster, governments face the pressure of DP requests for providing a high number of TH in a short time. By increasing the disaster intensity, this pressure escalates several times due to enhancing DP numbers and losing more alternative accommodations, which are not habitable in the aftermath of the natural disaster. To this end, to deal with the huge number of TH requirements the government needs to apply diverse temporary accommodations types by hiring several contractors. This research suggests that decision-makers choose steps scenarios for TH provision. The steps scenarios contain minimum and maximum TH requirements based on probabilistic disasters impacts, which have been designed based on local potentials and natural disasters intensity and severity. The outcomes of the steps scenarios are more accurate and reduce decision-making confusions after natural disasters when more scenarios have been considered between the minimum and maximum one. In the first step, decision-makers can choose more sustainable alternatives, such as available TH with regard to DP numbers and local potentials. In the next steps, other possible accommodations are considered when the DP requests for TH exceed the number of previous step´s alternatives, as shown in Fig. 6.3.

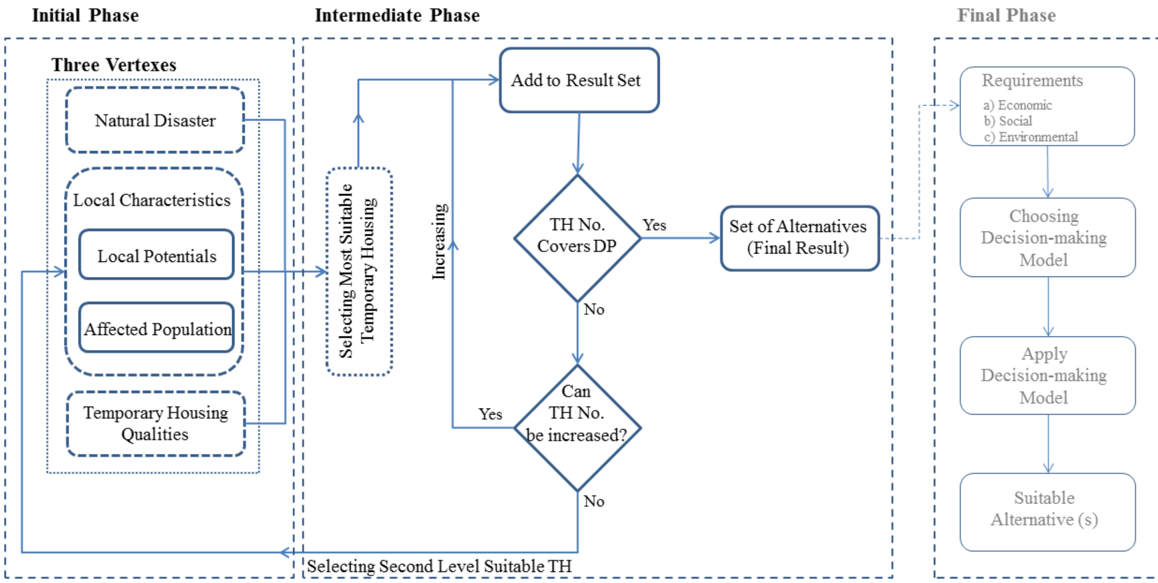

Fig. 6.2. General methodology for selecting the sustainable TH, including the three phases

This approach assists to use all local potentials as far as possible and avoids being vacant TH. As a result, the trend of the negative impact of TH reduces by increasing in the steps approach. Indeed, in the first stages of choosing TH, decision-makers use the suitable local potentials (step 1), which can be the sustainable options due to several aspects such as: expenses, transportation needs, flexibility, culture acceptance, fitting to the local climate conditions and local skilled labours, etc. (Barakat 2003; Félix et al. 2015; Johnson 2007; UNDRO 1982). Indeed, if the range of SI is considered between zero as the minimum value and one as the maximum value, an alternative with the closest SI to one is chosen in the first step. Then, if the chosen TH cannot cover the numbers of DP another alternative with less SI will be selected. However, sometimes to use the traditional local technologies cannot lead to obtain desired goals. In this regard, Da Silva (2010) stated that sometimes local technologies need to be changed or modified for being more resilient to future hazards, moreover, these maybe unusable due to shortfalls in materials and/or skilled labours. For instance, decision-makers avoided choosing timber technology, which had been used to construct pre-disaster traditional housing of Aceh, in the aftermath of tsunami 2004, due to shortfalls in some aspects. Therefore, this model generally gives an opportunity for decision-makers to choose the most sustainability TH with minimum weaknesses by considering the three vertexes.

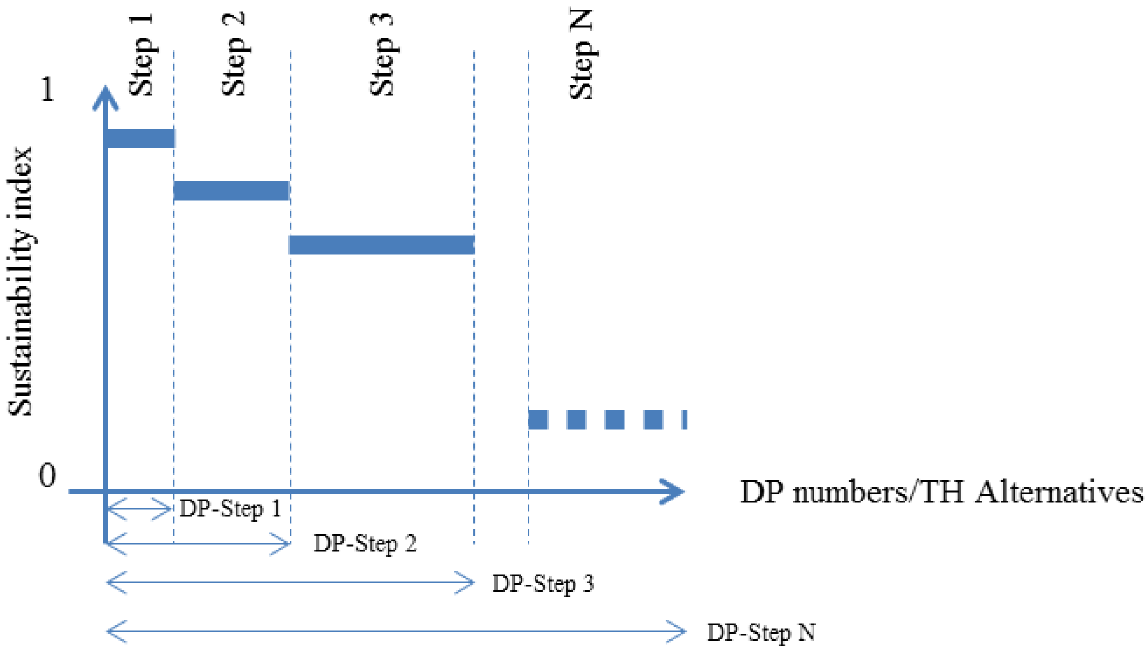

Fig. 6.3. Relation of sustainability indexes and DP in steps scenarios

Additionally, in an area, which there is no sufficient platform to determine DP numbers based on the three vertexes before disasters, it is possible to have steps scenarios only with regard to local potentials. Indeed, first alternatives with the less negative impacts are considered for DP numbers based on the capacity of these alternatives. The second alternatives with less SI than the first alternatives are applied as a second step scenario in case the number of DP increases and cannot be covered by the alternatives of the first scenario. In this situation, decision-makers can consider alternative scenarios based on available possibilities in a pre-disaster situation, and then, when DP numbers and number of habitable accommodations are evaluated aftermath of natural disaster, a fit scenario to the exiting condition can be chosen. However, this study has basically been designed for applying before natural disasters.

6.6. Sustainability indexes of temporary housing

According to the most relevant studies (Abulnour 2014; Arslan 2007; Davidson et al. 2007; Félix et al. 2013; Félix et al. 2015; Hui 2012; Johnson et al. 2006; Johnson 2007, 2009; Kennedy et al. 2008; Omidvar et al. 2011; Omidvar et al. 2013), essential factors that should be considered in order to implement adequate TH are as follow: (1) short delivery time, (2) fit with the culture of the DP, (3) acceptable privacy, (4) safety conditions, (5) comfort, (6) reusability, (7) DP participation, (8) suitable communication, (9) easily erect and transform, (10) low cost, and (11) minimum impact on environment. Additionally, assuming that the TH type which is used for short-term in specific situation, sustainability codes can be applied for this type of housing. Therefore, the sustainability indicators can be organized into three main indexes as: (1) economic, (2) social, and (3) environmental groups, as shown in Table 6.1; with regard to the aforementioned factors and sustainability concept based on (Halliday 2008; Häkkinen et al., 2012).

The main sustainability indicators have been defined in Table 6.1 meanwhile; each indicator can embrace several sub-indicators, which have been mentioned in the definition section. Additionally, sub-indicators can vary based on individual cases and TH life cycle phases, as shown in Fig. 6.1. Some indicators, such as *correspondence with local technologies*, can be assigned to the main vertex of the sustainability since this indicator has considerable impacts these whereas quite differently. Meanwhile, other indicators, such as the *maintenance cost* indicator which is required to be assessed in the operation phase, only belong to one phase. Furthermore, all indicators' priorities can completely be different from scenario to scenario for each case, moreover, from case to case. The factors´ priorities need to be evaluated by experts and local decision-makers.

6.7. Analysing

This study has defined sustainability indicators to choose the most suitable approaches based on the three vertexes. The designed model is applied to the two case studies, the recovery program of Bam earthquake, 2003, and Aceh earthquake and tsunami, 2004, in order to assess the change of the strategies in site location and TH type. The decision-makers of these two cases were forced to choose other alternatives during the prevision/construction and operation phases. This research sub-indicators, which are assessed through the cases, have derived the following two phases (prevision/construction and operation), as shown in Table 6.2.

Table 6.1. Definition of temporary housing sustainability indicators

Main Index	Main Indicator	Definition	Reference
Ec.	Provision cost	Considers all expenditure which is required for providing TH (e.g. renting, land price, construction cost, material cost, and utilities cost)	Halliday 2008; Häkkinen et al. 2012;
	Maintenance cost	Takes into account activity and material cost during and after DP usage	Halliday 2008; Hosseini et al. 2016a,b
S.	Health	Presents mental and physical factors of involved people in TH program and includes security, risk resistance, water and sanitation, infrastructures, communications	Da Silva 2010; Halliday 2008; Häkkinen et al. 2012
	Well-being	Embraces all those elements that provide comfort for DP: TH delivery time, access, facilities, privacy, climate comfort conditions, participation, etc. Additionally, this indicator embraces well-being of third-parties, such as neighbour acceptance	Da Silva 2010; Ganapati 2013; Hayles 2010; Kennedy et al. 2008; Pearce 2003
	Culture	Considers the fitting range of TH to DP´s culture	Hayles 2010; Johnson 2007; UNDRO 1982
En.	Resource consumption	Takes into account consumed material, water, and energy for all phases	Gangolells et al. 2009; Häkkinen et al. 2012; Halliday 2008; Hayles 2010
	Pollution	Includes all improper gas emissions and liquids leach	Häkkinen et al. 2012; Halliday 2008; Johnson 2007
	Solid waste	Takes into account waste materials	Gangolells et al. 2009; Häkkinen et al. 2012
	Reusability	Considers TH possibilities factors for second life	Arslan 2007; Häkkinen et al. 2012; Limoncu and Celebioglu 2006

As each case study has only two options which need to be evaluated in terms of SI and the main objective of this study is a steps scenario, the options are compared to each other by accepted, equal, and refused points. Furthermore, the camp site and private site of Bam are compared based on the indicators gathered in Table 6.2, as well as the tent and THUs of Aceh. However, in order to obtain the SI of each alternative, especially when there are more than two alternatives, a point assignment system or quantitative methods can be applied for each indicator which leads to more accurate results. Then the obtained parameters of each indicator can be arranged between 0 and 1 (as minimum and maximum of satisfaction value) directly or by considering the utilities theory. Finally, the SI of each case is evaluated from equation (6.1).

$$V = \sum \beta_i \, . \, \lambda_i \, . \, V_i \, (x_i) \tag{6.1}$$

$V_i \, (x_i)$: The value function of each indicator

λ_i : The weight of the indicator.

β_i : The weight of the main index, which embraces this indicator.

The weights of the indicators have been determined in University seminars by professors based on experiences as well as on references using the Analytical Hierarchy Process (AHP), as shown in Table 6.2. Besides, a sensitive analysis considering twenty-two different scenarios, consisting in modifying the weights of the requirements - in the range of 15% and 70% - has been carried out. These twenty-two scenarios have been conceived based on all weights, assigned by the professors to the requirements based on diverse conditions which even include the outliers. Meanwhile, the majority of cases have been assigned in the middle ranges, which can obviously be certain weights of the main indexes. Additionally, other approaches, such as the Shannon's entropy, have been applied to determine the weights of these research indicators (Hosseini, de la Fuentea, and Pons 2016b).

6.7.1. Bam scenario

The authorities of Bam decided to erect most camp sites on the outskirt of the Bam city because of the debris problems. Additionally, rental accommodations strategy could not be applied due to the huge amounts of the damaged buildings. Therefore, the decision- makers decided to provide camp sites, which needed site preparation activities, utilities, and so on, or private site. According to Khatam (2006), 10%-20% of the THUs on camp site were never occupied. Some units on camp sites were applied to reside engineers and aid groups, who came to the Bam city from other cities owing to shortfalls in the local human resources. When DP did not desire to settle on the camp site, the camp site strategy was changed into the private site in the middle of the road. Additionally, some vacant site, especially after erecting THUs on private properties, met up with social problems, and consequently authorities forced to dismantle and remove the troubled camp site. The change of the decisions was more suitable for the DP of the Bam earthquake, however, the change led to a waste of time and funding.

Table 6.2. Case studies' alternatives assessment based on sustainability indicators

Case	Alternative	Economic		Social					Environmental	
		(I_1)	(I_2)	(I_3)	(I_4)	(I_5)	(I_6)	(I_7)	(I_8)	(I_9)
Weight		75%	25%	45%	15%	25%	10%	35%	30%	35%
Bam	Camp	R	R	R	R	R	A	A	E	E
	Private	A	A	A	A	A	R	R	E	E
Indonesia	Tent	A	R	R	R	R	E	A	A	R
	THU	R	A	A	A	A	E	R	R	A

(I_1) Expense; (I_2) Maintenance; (I_3) Health; (I_4) Well-being; (I_5) Culture; (I_6) DP Distribution; (I_7) Consumption; (I_8) Pollution; (I_9) Reusability

(A: accepted; E: equal; R: refused)

Khazai and Hausler (2005) stated the DP were concerned about their previous properties and also the long distance of sites, therefore THUs on camp site were refused. Additionally, according to DP´s act, which adding some components to their THUs for providing more private areas, demonstrates that the rejection could be related to the DP culture, besides the DP´s concerns. Beyond the mentioned problems, the assessment of other related indicators, as shown in Table 6.2, confirms that other differences of these two alternatives play important roles for choosing a sustainable one. In this regard, the maintenance of THUs which were built on private yard of DP´s previous housing was better than those in the camp site due to the sense of belonging. On the other hand, private sites needed more transportation compared to the camps and consequently higher energy consumption.

6.7.2. Aceh scenario

Several international and Indonesian organizations were involved in the recovery program of Aceh aftermath of the earthquake and tsunami in 2004. The authorities decided to conceal the TH phase to avoid wasting the resources for these accommodations. Therefore, the DP was supposed to stay in tents and barracks until the permanent housing was finished. The tents, which were used for the DP to reside, could not withstand the tropical sun and rain (Da Silva 2010; Steinberg 2007). In this sense, the decision-makers changed the strategy and provided THUs for the DP. However, some of THUs have been used as an initial part of the core housing.

Even if the tents would have resisted the tropical conditions, from the DP´s satisfaction point of view, the tents also had some weaknesses compared to the THUs, as shown in Table 6.2. The tents needed to be replaced totally, when the tents started to decay. This indicates that the tents did not have the capacity to be maintained, however, the cost of the tents was not comparable with THUs. On the other hand, the other characteristics of THUs, such as reusability, health and well-being provision, and so on, were considerably higher than the tents. These different characteristics of various TH types leads to choose each alternative based on individual conditions.

6.8. Results and discussion

As shown in Table 6.3, the most sustainable alternatives of each case are specified based on the different weights of their indicators, which have been obtained by three approaches. These three weights of indicators have been determined by the seminars' results, which have been presented in Table 6.2, considering same weights for all indicators (Equal), and Shannon's entropy. The results show that the equal weights of all indicators cannot be reliable methods for two cases, as most researchers have mentioned the importance of involved indicators in TH issue.

In the Bam case, the results obtained clearly demonstrate that erecting TH on DP´s private properties is more sustainable and well-accepted than on camp sites. The private properties approach is ranked on the first stage by considering several scenarios based on diverse weighting distributions of the main indexes. Indeed, the private site has considerably more benefits and satisfies all stakeholders' point of view compared to the other alternatives, besides the problems mentioned by the researches for rejection of TH on camp site. Therefore, the private site strategy should have been applied at first in this case, due to its higher SI. If there was no more private land for providing TH on the DP´s previous house yard-in other words, the population density would be higher, the decision-makers would apply the camp site as a second ranked sustainable alternative. However, decision-makers changed the strategy after facing the DP´s reluctance to move to camp sites and then provided almost two-third of the total THUs on the yard of private properties.

In the Aceh case, different results have been derived from the diverse methods which need to be analysed. As aforementioned, the SIs of several cases with regard to the same weights of all indicators only have been assessed to determine the importance of the indicators' priorities. To this end, the results of the Aceh case, which have been obtained from two indicator weights approaches: seminars and Entropy, are considered based on the twenty-two scenarios.

As shown in Fig. 6.4, changing the weights of economic and social indexes can change the SI trends of the Aceh alternatives. On the other hand, the SI presents a non-monotonic sensitivity regarding the environmental index, as can be seen in the trends. However, an increase of 55% of the environmental index weight (from 15% to 70%) leads to change in the SI in a disorganized way (non-monotonic) between 0.33 and 0.64. If the economic or social weights increase, tents or THUs, respectively, become more sustainable alternatives. In this regard, a decrease of 55% of the social index weight (from 15% to 70%) leads to an almost monotonically SI increase of the tent from 0.25 to 0.63 and to decrease SI of the unit from 0.72 to 0.36. Therefore, the steps scenario algorithm presents diverse alternatives as the most suitable results based on different requirements and conditions.

To this end, if the quality life of DP - in other words, social aspects, was the first priority of the decision-makers, the THUs could be the most sustainable TH for the Aceh recovery program. The decision-makers could provide THUs for DP initially, and then if the number of TH could not cover all DP, tents, the second ranked SI, would be applied for those people whom had not been residing in TH. However, if the economic aspects were the first priority of the authorities, tents would be chosen as the first alternative. In the next stage, if the number of tents, which could be prepared for DP, was less than those required by the DP, the THUs strategy, as the second ranked SI, could be utilized.

Table 6.3. Most sustainable alternative for each case based on different indicator weights

Case	Weight / Main Index / Indicator	70Ec/15S/15En	50Ec/30S/20En	50Ec/25S/25En	48Ec/30S/22En	48Ec/22S/30En	47Ec/35S/18En	47Ec/18S/35En	45Ec/25S/30En	42Ec/36S/22En	42Ec/22S/36En	38Ec/33S/29En	38Ec/42S/20En	36Ec/42S/22En	35Ec/47S/18En	30Ec/48S/22En	30Ec/45S/25En	25Ec/50S/25En	20Ec/50S/30En	20Ec/30S/50En	15Ec/55S/30En	15Ec/70S/15En	15Ec/15S/70En
Bam	**Seminars**	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
	Equal	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	C
	Shannon's Entropy	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	C
Aceh	**Seminar**	T	T	T	T	T	U	T	T	U	T	U	U	U	U	U	U	U	U	U	U	U	T
	Equal	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	T
	Shannon's Entropy	T	T	T	T	T	T	T	T	T	T	T	U	U	U	U	U	U	U	T	U	U	T

(P: private yard of DP´s previous housing; C: camp site; T: tent; U: unit/THU)

In general, the strategy of the recovery programs is related to several factors, which as has been explained, can have opposite impacts depending on different cases. As the results show, each alternative for each case has the low and high SIs based on different requirements priorities. Therefore, to deal with the post-disaster housing issue it is necessary to determine strengths and weaknesses of possible strategies based on the three main vertexes (see **Chapter 3**). Then, the most suitable alternative can be specified based on the individual requirements of each case. Indeed, to make a proper decision about this issue with the maximizing the stakeholders' satisfaction, it is required to detect problems, define possible responses, determine all characteristics of responses based on different conditions without prejudice, and choose an appropriate alternative by considering correspondence between the alternative´ characteristics, problems, and requirements, as the model of this study proposes.

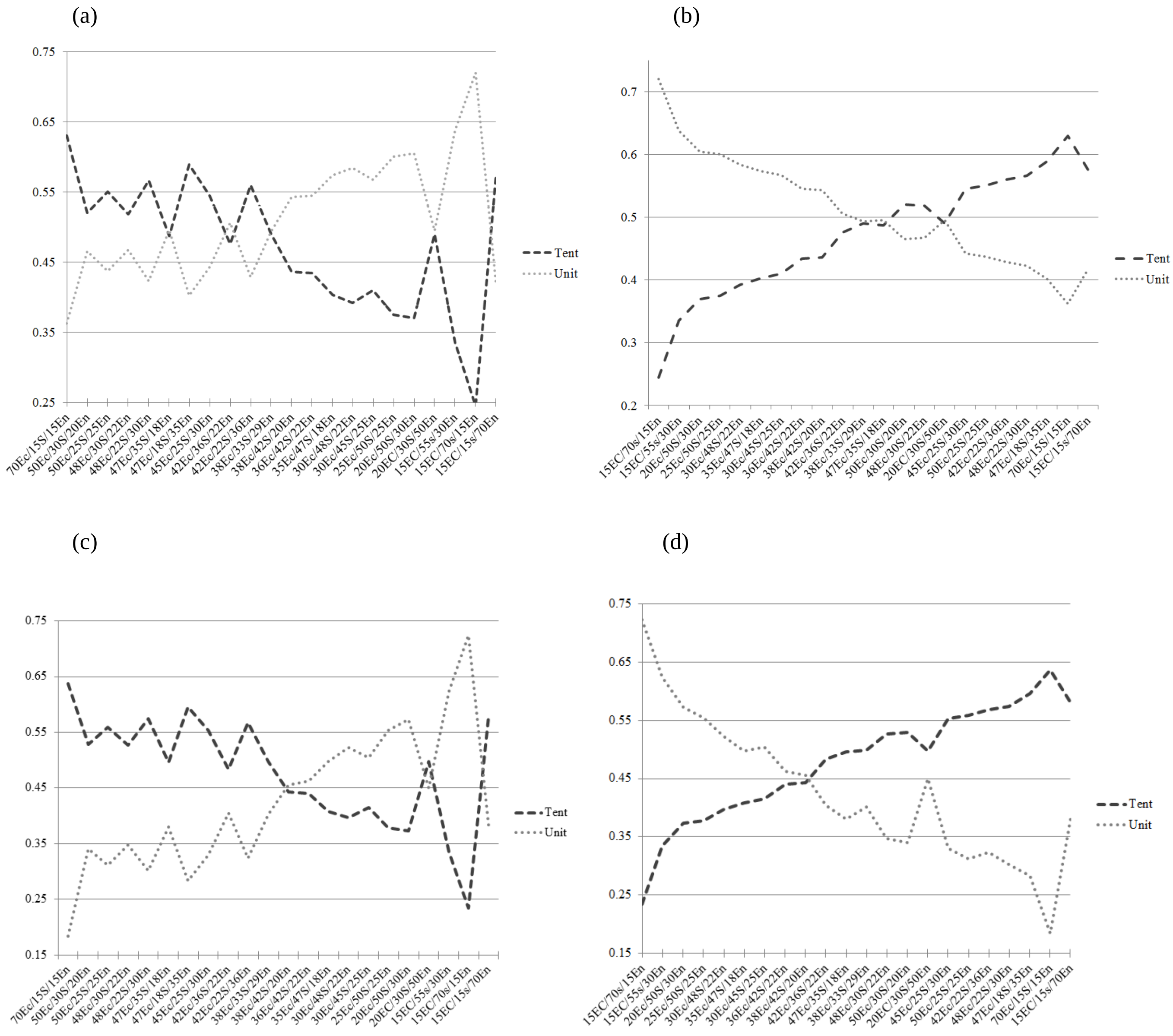

Fig. 6.4. Sustainability indexes of the Aceh recovery program alternatives considering: (a) decreasing economic weights by the seminars; (b) decreasing social weights by the seminars; (c) decreasing economic weights by the Entropy; (d) decreasing social weights by the Entropy

6.9. Conclusions

A new model configured to assess the sustainability of post-disaster TH alternatives has been proposed in this research. In this regard, the Bam and Aceh post-disaster situations, which faced to the challenge of having to change their recovery strategies in terms of site location and TH strategy, have been considered as example cases. This model, steps scenario, offers an opportunity for decision-makers to choose beforehand the alternatives, by considering the following aspects: maximizing the social aspects, minimizing the public expenditures; and minimizing the negative environmental impacts, by coupling sustainability concepts and criteria. Indeed, this model could play an important role in preventing that decision-makers select TH with a high negative outcome with regard to the three main vertexes (local, natural hazard, and TH characteristics). The following conclusions also can be derived from this research:

- The sustainability indexes of the alternatives for the Bam and Aceh cases demonstrate that decision-makers should have changed the initial strategies. However, changing the initial strategies had negative implications such as wasting time and investment. In this sense, these two cases, the decision-makers needed a model as the one presented in this study, in order to recognize the most suitable alternative at the initial stage of the planning phase.
- Suitability of TH strategy is determined based on the three vertexes and the indicators' priorities in this study. Therefore, each strategy needs to be considered; even those that seem to have substantial negative impacts, because strategies with evident weaknesses may be more suitable when compared to other alternatives by considering the whole life cycle of TH, requirements of all beneficiaries, and individual local conditions.

Furthermore, this study provides a platform for future researchers by considering this model for other cases by providing an analysis of previous cases and pre-planning for areas prone to natural disasters. All the factors that influence on recovery programs, including local conditions, can be determined by applying this model directly. As a result, more accurate and more resilient pre-disaster planning can be designed if optimized weights are assessed.

Chapter 7

Multi-criteria Decision-making Method for Sustainable Site Location of Post-disaster Temporary Housing in Urban Areas

7.1. Introduction

Over the last decade, 200 million people have been affected by natural disasters and hazards, 98% of whom lived in developing countries where climate change causes extreme temperatures, increased flooding, intense heat waves, and droughts (Aquilino 2011). Those who lost their homes to natural disasters needed somewhere to live while their houses were rebuilt or needed to find alternative accommodations (Collins et al. 2010; Davis 1982). The years between living in emergency accommodations and permanent houses present a time gap that needs to be bridged by temporary housing (TH) (Johnson et al. 2006). However, these temporary houses have, to date, been criticized for their inability to meet the expectations of displaced people (DP) (Chen 2012).

In general, according to most relevant studies (Arslan 2007; Chandler 2007; El-Anwar et al. 2009 a, b; Félix et al. 2013; Johnson 2007 a), TH programs have been criticized on several issues: (1) TH delivery time, (2) social and welfare quality, (3) TH locations, (4) cost of the TH implementation process, and (5) impact on the environment.

Improper site selection is a major problem that has caused dissatisfaction with regard to the DP of previous natural disasters, such as Turkey-Istanbul in 1999 (Johnson 2007b, c), Iran-Bam in 2003 (Ghafory-Ashtiany and Hosseini 2008; Khazai and Hausler 2005), Italy-L'Aquila in 2009 (Rossetto et al. 2014), and the Great Eastern Japan Earthquake in 2011 (Shiozaki et al. 2013). In general, according to most relevant studies, the site location factors that cause DP to be dissatisfied are: (1) losing previous social communities; (2) not fitting in new communities; (3) inadequate access to urban facilities, such as shopping centres, recreation centres, and so on; (4) large distance from the new location to previous activities (job, university, and previous private property); and (5) concern about private property. For instance, Khazai and Hausler (2005) declared that some of the Bam TH units remained vacant due to their site location.

Additionally, according to (El-Anwar et al. 2009 a; Johnson 2002), finding a suitable TH location is the main reason for delaying the provision of TH. Furthermore, according to Johnson (2007a), the site location for TH can have a substantial impact on public expenditures. Johnson (2007a) stated that TH sites located on the outskirts of cities needed further development because of their distance to basic necessities, such as schools, clinics, and so on. Therefore, the site location of TH has considerable effects on the provision of TH as well as public expenditure, in addition to the aforementioned social impacts.

Numerous TH studies have considered the importance of selecting an appropriate location for a DP temporary settlement. Some have assessed site selection exclusively, covering topics such as guidelines for shelter location (Handbook for emergencies 2000), site selection indicators (Corsellis and Vitale 2005; Davis & Lambert 2002; Soltani et al. 2014), strategies of site selection (Kelly 2010), selection of fixed seismic shelters by the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) (Chua and Su

2012), urban shelter locations based on covering models (Wei et al. 2012), hierarchical location models for earthquake-shelter planning (Chen et al. 2013), site selection and decision-making methods (Omidvar et al. 2013), and optimizing TH assignments to minimize displacement distance (El-Anwar and Chen 2012).

All of these research studies have contributed to the development of TH, but only a few have considered TH optimization (El-Anwar et al. 2009 b) and sustainable construction (El-Anwar et al. 2009 c). The number of studies in which urban areas have been considered is also small compared to those dealing with rural areas.

However, it is necessary to assess urban areas and to do so individually due to their own characteristics, such as concentration of population, homes and other buildings; transportation infrastructure; and industries (IFRC 2010).

Additionally, as different cities have various local living standards and characteristics, the weight of these model indicators, criteria, and requirements are different from one metropolitan area to another (Davis 1982; Johnson 2007a). Therefore, because site selection for TH is a process that involves various criteria (Kelly 2010; Omidvar et al. 2013) and different stakeholders, decision-makers need help dealing with the selection of the most suitable options by considering multiple criteria with respect to the requirements and characteristics of all of the involved stakeholders.

The **objective** of this chapter is to present a new model that is capable of selecting an optimized location for TH by assessing economic, social, cultural, and environmental aspects. To obtain the optimal satisfaction of the involved stakeholders, this model was designed to: (1) maximize the well-being of DP, (2) minimize the negative impact on neighbourhood life, (3) minimize TH public expenses, (4) minimize the negative impact on the environment, and (5) maximize the well-being of people involved in the TH construction process (e.g., engineers, workers). The site chosen in the present model specifically embraces the TH phase based on Quarantelli's definition of phases (Quarantelli 1995), even though the site can be used for the emergency shelter and temporary shelter phases as well. Additionally, the chapter provides a method meant to choose and prepare TH locations during the normal situation (pre-disaster).

This new model has been applied to find the best site location for TH in the case of a probabilistic earthquake of Mosha's fault in Tehran, Iran. This case is based on reports from the Japan International Cooperation Agency (JICA), which has assisted the Iranian government in providing a disaster management master plan for Tehran since 1999 (JICA 2000).

7.2. Methodology

A holistic approach was used in this study to present a TH process that used site selection as one of the significant components of TH implementation. This methodology has four phases: (1) data collection, (2) data analysis, (3) model design, and (4) model application, as shown in Fig. 1. In the *data collection phase*, the necessary information on TH is obtained through comprehensive literature reviews, recovery reports, surveys, and TH guidelines. In the *data analysis phase*, the stakeholders and characteristics of TH are defined. Then, the defined characteristics are assessed to distinguish the negative and positive points according to their strengths, weaknesses, opportunities, and threats mode (SWOT). In the *model design phase*, the requirements tree is based on the local characteristics of the case study and its demands.

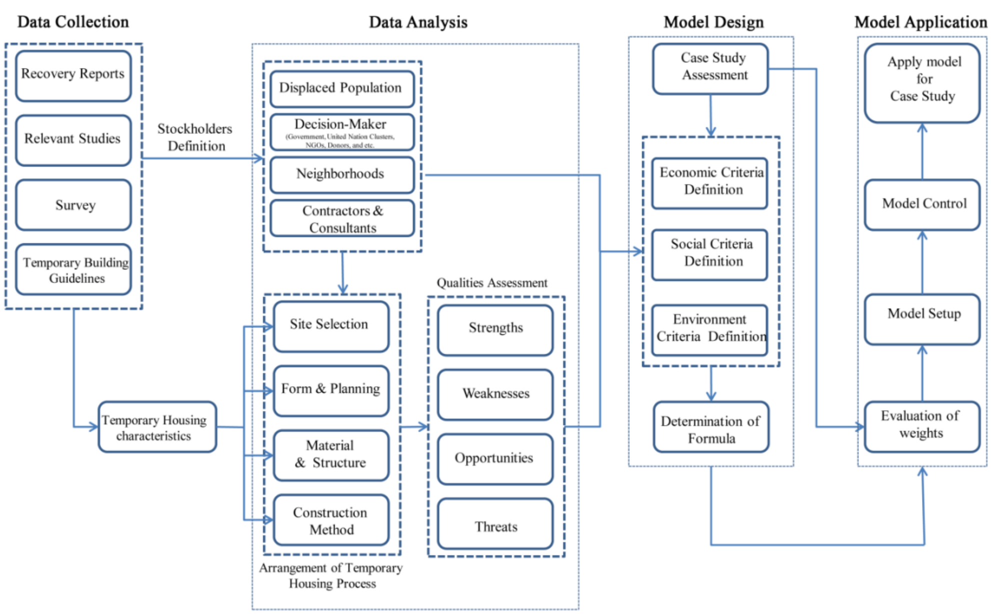

Fig. 7.1. Methodology for considering the whole TH process and the sustainability assessment method based on MIVES

As the objective of this chapter includes site selection exclusively, the estimation of DP is considered to determine the demand area of the TH site, as shown in Fig. 7.2, before defining the requirements tree. The designed tree must contain minimum indicators, which are independent from each other and calculable in formula.

In the *model application phase*, the weights of the indices are evaluated by a group of multidisciplinary experts who use the Analytical Hierarchy Process (AHP) (Saaty 1990) based on previous studies and local characteristics. Decision-makers also define alternative sites that have the ability to be used as locations of post-disaster TH with regard to the determined requirements and the relative weights of these requirements. The decision-maker can decide to have some small distributed sites in the city or a unique large site, which usually located on the outskirts.

Because the data collection and analysis phases of site selection for TH have already been considered in the introduction of the research, the following section defines the model design for site selection.

Fig. 7.2. Model implementation for site selection

7.3. Sustainability assessment of post-disaster temporary housing

According to MIVES, a specific tree, which is shown in Fig. 7.3, was developed to assess the sustainability of site selection for post-disaster TH based on data collected from extensive technical literature and seminars that have been given by multidisciplinary engineers who are expert in this subject.

The first level of the tree includes the economic, environmental and social requirements; the second hierarchical level includes the five criteria; and the last level includes the nine indicators. Unlike the requirements and criteria, the indicators are measurable variables to quantify each alternative site.

The *economic requirement* (R_1) assesses the investment of each proposed site that could be a location for TH. The *social requirement* (R_2) takes the impact of each alternative site, in terms of the social aspects on DP as users of temporary houses and third parties who are involved in TH, into account. The *environmental requirement* (R_3) assesses the environmental effects of all of the processes related to the site location throughout all of the phases of the life cycle.

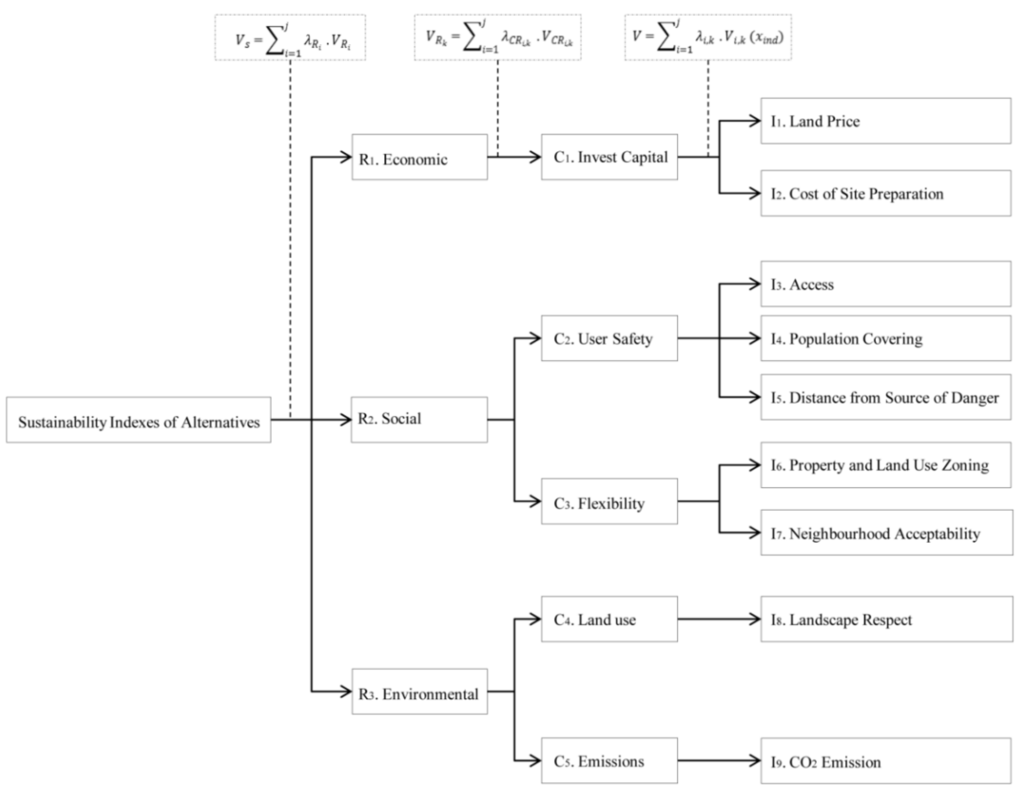

Fig. 7.3. Requirements tree designed for this model

7.3.1. Definitions of indicators

I_1. *Land price indicator* evaluates the cost of land per square meter (cost/m^2). As it has already been mentioned, it is possible to have sets of several sites whose total area is equal to or close to the required area.

I_2. *Cost of site preparation* assesses the amount of expenditure during the site preparation process. I_2 locates the site that requires the minimum investment for preparation activities. Cost of site preparation is related to the following site characteristics: (1) slope, (2) topography, (3) type of soil, (4) type of plants, (5) level of groundwater, (6) access, (7) mobilization, and (8) utilities and utility vulnerability after a disaster. The experts have estimated the cost of site preparation for each alternative in cost/m^2.

Because the selected site may be located in a district where the urban facilities (water pipes, power cables, etc.) would be damaged by natural disasters, the δ factor prevents a site in a district where the urban facilities will need to be repaired in the aftermath of a natural disaster from being chosen. The δ factor presents the quality of the utilities after the disaster based on professional prediction. The system assigning points has been employed for this factor.

The indicator called *efficient use of investment* ensures that the chosen alternative site(s) has an area equal to or close to the required area. This indicator has been eliminated because most alternative sites are owned by the government, one of the main investors; it is possible to use a portion of each site to avoid extra expenses.

The dimensions of the site are defined by the prediction of DP multiplied by the required area per person. Handbook for emergencies (2000) suggests a figure of 30 m^2 per person, which includes the necessary area for roads, foot paths, educational facilities, and so on. Davis and Lambert (2002) stated that 45 m^2 per person is necessary for temporary settlements according to the sphere project. Aside from the number of DP, other factors, such as building design varying from flat houses to multi-level houses, average number of people in households, and local characteristics, impact the area of site location.

I_3. *Access* considers the quality and time of access for DP, third parties and emergency services from the beginning of the TH process to its end. I_3 takes into account the access for a period of time that contains the (a) construction phase, (b) operation phase in normal situations (pre-disaster), and (c) operation phase as a TH location (post-disaster).

During the construction phase, the access for people involved in construction (employees, workers, engineers, etc.) is assessed. During the operation phase in post-disaster periods, two issues are assessed: (1) the quality of DP access to other parts of the city and (2) the quality and time of access for emergency services (medical, fire fighter, police, etc.) to the site. Because the access in the pre-disaster construction and operation phases is the same as the access for DP, only the accessibility for the operation phase during the post-disaster period is considered. Thus, I_3 takes into account the accessibility of DP and emergency services.

Therefore, the quality of access for DP is determined by using the following point assigning system for the access coefficient (α).

The access of emergency services takes into account two factors: (1) access time for emergency services in minutes and (2) quality of emergency services, which embraces (a) the quantity and quality of equipment and (b) the number of emergency services that cover the location of the TH with the same function that is considered by the coefficient β. This coefficient is measured by assigning points. Additionally, this chapter assumes that the weights of emergency services are equal.

As the accessibility for emergency services is vitally more important than access for DP, the coefficient for the accessibility of emergency services is 70%, and the coefficient for the accessibility of DP is 30%. These coefficients can change according to each situation.

I_4. *Population covering indicator* analyses alternatives to: (1) maximize the coverage of DP, (2) distribute chosen sites throughout the city (decentralization of temporary sites), and (3) distribute facilities based on the distribution of the displaced population.

In other words, I_4 helps decision-makers obtain two goals: (1) there is no region where the DP have problems due to area deficiency and (2) no selected site remains empty or forces DP to move to another site that is far from the previous local zone of the DP. Thus, the population coverage is evaluated by equation (7.1).

$$PC_i = \sum_{1}^{m} \left(\frac{D_{a_i \to R_m}}{P_{R_m}} \right) \quad (7.1)$$

PC_i : Population covering parameter for alternative site *i*

$D_{a_i \to R_m}$: Distances from the gravity centre of the alternative site *i* to the gravity center of the region *m*

m : Number of assessed regions

P_{R_m} : Predicted displaced population in the region *m*

I_5. The *distance from the sources of danger* indicator has been designed because the chosen site should be located far from the sources of dangers, such as secondary hazards that could risk the integrity of the DP.

In addition to the previous distance from the hazardous zone, the danger level of the source should be considered. Therefore, a system assigning point has been used to assess the danger level of the source that is defined with the γ-coefficient.

The *user safety criterion* (C_2) could also include an additional indicator, *preparation activities time*, which is vital for DP. However, this model does not consider the time of site preparation because the assumption of this study is to choose and prepare locations of TH during the normal situation (pre-disaster).

I_6. *Property and land use zoning indicator* considers site conditions in terms of land use, land property, and legal restrictions based on a comprehensive master plan. A system assigning points has also been used.

I_7. *Neighbourhood accessibility indicator* takes into account the impact of TH on the neighbourhood environment. This study has assessed the following items as sub-indicators: (1) density, (2) quality of medical care services, (3) green area, and (4) school capacity. Additionally, the weights of the previously mentioned sub-indicators are assumed to be equal.

I_8. *Landscape respect indicator* takes into account the impact of TH on ecosystem changes, such as isolated district or access limitation, damage from sewage, excavation, acidification, and other negative influences. The system assigning points has also been employed for this indicator.

I_9. Building construction causes high energy consumption and CO_2 emissions during the life cycle stages of construction, usage, and demolition (Pons and Wadel 2011). Thus, indicators should be designed to assess the impact of the TH site on the environment in terms of CO_2 emissions and energy consumption based on the Life Cycle Assessment (LCA). The environmental impacts of the site location embrace only the construction and demolition phases: (a) construction phase, considering only transportation and site preparation activities and (b) demolition phase, considering only transportation.

Therefore, *CO_2 emission indicator* (I9) was designed to measure the amount of CO_2 emissions according to two aspects: (1) preparation activities for each site during the construction phase and (2) required transportation for each site during the construction and demolition phases.

Because the value of preparation activities has already been calculated for the economic requirement, according to the MIVES concept, this indicator should be independent, and the consequent amount of CO_2 emissions due to preparation activities is not considered. Therefore, only the CO_2 emissions from transportation for each alternative are assessed by using the formulas proposed in the 1996 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories destructive gas emissions and energy consumption (Eggleston and Walsh 2000).

The values of the model parameters suggested by Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (2000) are the same for all of the alternative sites, except for the activity parameter that includes the fuel consumed or distance travelled. Thus, the amount of CO_2 emissions from transportation depends on the activity parameter. Consequently, I_9 calculates the total distance travelled for each alternative site, which includes the distances from the material resources centre and the landfill site to the alternative site.

Other polluting emissions and energy consumption have values proportional to the indicator CO_2 emissions (Pons and Aguado 2012) for each of the studied alternatives. Thus, instead of assessing all polluting emissions and energy consumption, only the CO_2 emissions are assessed. Additionally, TH water consumption is not considered because it is negligible during most of phases such as construction and demolition.

7.4. Application example

An application example illustrates all of the phases of the sustainability decision-making model to choose an adequate site location for post-disaster TH in Tehran based on the Mosha fault scenario. The example includes four of the twenty-two Tehran districts. The population of these districts is almost 1,200,000, as shown in Table 7.1. The assessed scenario is based on reports from the Japan International Cooperation Agency (JICA) (JICA 2000). This Agency, together with the Center for Earthquake and Environmental Studies of Tehran (CEST), assessed potential earthquakes in Tehran in 2000 (Omidvar et al. 2013). This study evaluated damaged buildings and casualties in the aftermath of probabilistic earthquakes based on four different scenarios: the Rey fault model, the North of Tehran fault model, the Mosha fault model, and the floating model (Omidvar et al. 2013). This research considers a model for choosing an adequate site location for post-disaster TH in Tehran based on the JICA and CEST results for the Mosha fault model.

According to the JICA and CEST study (2000), if a probabilistic earthquake occurs during the day, it will cause almost 18,000 casualties, more than 610,000 DP, and 90,000 damaged residential buildings in total. The statistics for damaged buildings evaluated only residential buildings as blocks without considering the number of total residential units in one block. The estimated displaced populations of the four districts considered add up to approximately 160,000 people. Because it is assumed that one-third of the DP will be settled in multi-level houses in the camp, the total area demanded is nearly 100 hectares, corresponding to 20 square meters per person. According to United Nations High Commissioner for Refugees (UNHCR) and the sphere project, the area demanded in the camp ranges between 30 and 45 m^2/pers. However, based on the assumptions of this study and the land scarcity in Tehran, two-story and three-story TH units have been designed. Thus, a demanded area of almost 20 m^2/pers has generally been obtained.

Based on the required area (100 ha) for this case, alternative sites with the required initial features have been selected. There are six alternatives, which include twenty-three sites in or around the zones of this application example. There are four individual sites and two sets. The areas of these four alternative sites (A_1-A_4) are approximately equal to or larger than the area demanded. The last two alternative sets include divisions: set B includes five sites (B_1-B_5) with a total area of 100 ha and set C includes seventeen sites (C_1-C_{14}, B_2, B_4, and B_5), including three sites of set C in common with set B, as shown in Fig.7.4. All of these sites are open spaces that need site preparation, except for C_{12} (parking lot) and C_{14} (barracks). Eighteen sites are located in the four chosen districts, and five sites (A_1, A_2, A_4, B_4, and B_5) are located outside of these four districts. A_1 and A_2 are located outside the city centre, close to entry roads.

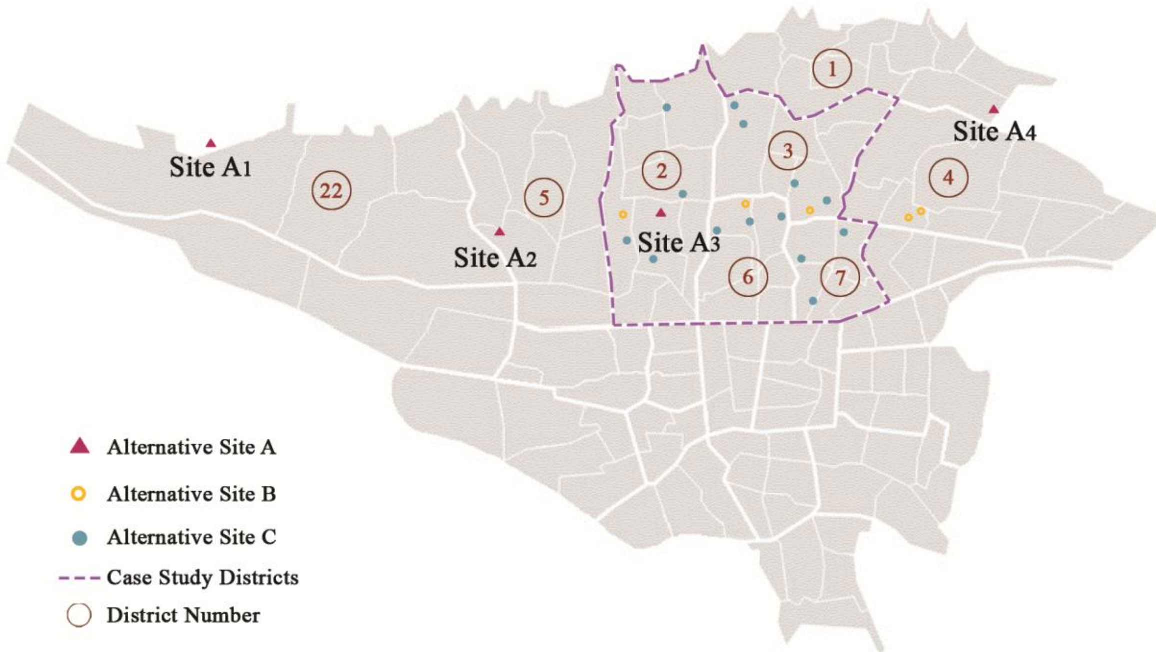

Fig. 7.4. Tehran map (including the case study districts and alternative sites)

7.5. Analysis

By determining a value function for each indicator according to the MIVES equations, it is possible to quantify each attribute. According to Alarcon et al. (2011), for the determination of the satisfaction value for an indicator, there are four stages: (1) to determine the tendency (increase or decrease) of the value function, (2) determine the points to find S_{min} and S_{max}, (3) determine the shape of the value function (linear, concave, convex, S-shaped), and (4) determine the mathematical expression of the value function.

According to Alarcon et al. (2011), when satisfaction increases rapidly or decreases slightly, a *concave-shaped* function is the most suitable. The *convex* function is used when the satisfaction tendency is contrary to the concave curve case. If satisfaction increases/decreases steadily, a *linear* function is presented. A *S-shaped* function is used when the satisfaction tendency contains a combination of concave and convex functions

The value function implemented in MIVES is based upon the general exponential equation. This function permits the simulation of a wide range of responses by properly modifying the constitutive parameters (Pons and de la Fuente 2013).

The values of X_{min} and X_{max}, and the function shapes have been derived from international guidelines, the scientific literature, Iranian principles, and background of experts who participated in seminars, as shown in Table 7.2. These functions have the following shapes: four decrease, of which two decrease in a concave fashion (DCv) and two decrease in a convex fashion (DCx), and five increase, of which three are S-shaped (IS) and two increase in a convex fashion (ICx). X_{min} and X_{max} are defined for each indicator, as shown in Table 7.2.

Like I_5, S-shaped functions have a minimum satisfaction that drops to zero for values that are smaller than a defined lower indicator value, a maximum satisfaction that reaches 1 for values greater than a defined upper indicator value, and an increasing satisfaction from almost 0 to 1 for values between the defined lower and upper indicator values. Concave functions represent indicators in which the maximum value (such as population covering, I_4) is demanded (Alarcon et al. 2011). The convex I_1 function aims to promote the reduction of land price. The minimum X_{min} is the lowest land price per each square meter in Tehran's regions ($2.4 \cdot 10^7$ IRR.). Additionally, satisfaction decreases rapidly when the building cost increases; a decreasing convex (DCx) curve is assigned for the tendency of this indicator value function, as shown in Fig. 7.5.

Four indicators (I_3, I_6, I_7, and I_8) have been measured by points. The maximum X_{max} has a maximum value of 1, corresponding to the geometric mean value of the sub-indicators for each indicator for I_3 and I_7. These sub-indicators have five parameters that are similar to the indicators shown in Table 7.3. Finally, by defining a value function according to equation (2) for each indicator, it is possible to assess each attribute.

Table 7.1. Relevant information of the case study districts

		Case study districts				Other districts (where the alternative sites have been located)				
		District 2	District 3	District 6	District 7	District 1	District 4	District 5	District 22	References
Area (km^2)		48.2	29.4	21.5	15.4	64	61.4	54.5	61.1	Implementation of the 2011 Iranian Population and Housing Census 2011; Iran: Tehran City 2014; JICA 2000; zayyari et al. 2012
pop	Census 1996	458089	259019	220331	300212	249676	663166	427995	56020	Implementation of the 2011 Iranian Population and Housing Census 2011; JICA 2000
	Census 2011	632917	314112	229980	309745	439467	861280	793750	128985	
Green area (km^2)		6.8	3.9	2.8	0.8	3.8	7.7	7.6	1.8	Atlas of Teheran Metropolis; Implementation of the 2011 Iranian Population and Housing Census 2011; JICA 2000; Mohammadzade Asl et al. 2010; zayyari et al. 2012
Medical service		418	368	577	254	232	277	328	36	Implementation of the 2011 Iranian Population and Housing Census 2011; JICA 2000
Police station		35	39	78	52	75	67	5	41	JICA 2000; Mohammadzade Asl et al. 2010
Fire station		4	4	2	2	2	5	5	2	Alavi et al. 2013; JICA 2000; Mohammadzade Asl et al. 2010
Educational centre		735	586	795	431	572	627	586	63	Mohammadzade Asl et al. 2010
Urban development level (%)		77.94	89.96	9.91	72.48	100	59.79	51.49	52.56	Atlas of Teheran Metropolis; Mohammadzade Asl et al. 2010
Damaged building proportion (%)		11.1	16.4	12.7	12.8	17.9	13.8	8.6	6.8	JICA 2000
Causalities proportion (%)		0.1	0.2	0.2	0.2	0.3	0.2	0.00	0.00	JICA 2000

Table 7.2. Parameters and coefficients for each indicator value function.

Indicator	Unit	X_{max}	X_{min}	C	K	P	Shape	References
I_1	IRR/m^2	$1.2\cdot10^8$	$2.4\cdot10^7$	$1.2\cdot10^7$	0.001	2	DCx	JICA 2000; Prices of Housing Market in Tehran 2010
I_2	IRR/m^2	40000	0	$3.2\cdot10^4$	0.2	2.5	DCx	Pricing Schedule of Buildings in Iran 2012
I_3	pts.	1	0	0.35	0.2	3	IS	Alavi et al. 2013; Atlas of Teheran Metropolis; It's About Time: Why emergency response times matter to firefighters and the public 2010
I_4	m/pop	3.00	0.3	0.3	0.3	0.9	DCv	Amiri et al. 2013; JICA 2000; Mohammadzade Asl et al. 2010
I_5	m	2000	0	750	0.2	4.5	IS	Chua and Su 2012; Nojavan and Omidvar 2013
I_6	pts.	1	0	1.5	1	5	ICx	JICA 2000
I_7	pts.	1	0	0.3	0.2	3	IS	JICA 2000; Mohammadzade Asl et al. 2010
I_8	pts.	1	0	1.2	1	3.5	ICx	JICA 2000; zayyari et al. 2012
I_9	km	27	0	15	2	0.9	DCv	JICA 2000

7.6. Weight assignment

In this step, the weights of the requirements, criteria, and indicators are assigned by using the Analytical Hierarchy Process (AHP) based on previous studies, local characteristics, and the knowledge of the experts involved in seminars. Several individual meetings and seminars were organized and held by professors of the Universitat Politècnica de Catalunya, Universitat Internacional de Catalunya, Tehran Disaster Mitigation and Management Organization, and the experts of the Tehran Disaster Mitigation and Management Organization to determine the weights (λ_i). Regarding the weight distribution obtained for each of the elements constituting the requirements tree (Table 7.4), it should be emphasized that the CVs (coefficients of variation) of each λ_i did not exceed 10%, except the outliers that were initially rejected. Thus, the mean values of λ_i were used throughout the sustainability analysis (see del Caño and Gómez (2012) for an uncertainty treatment approach).

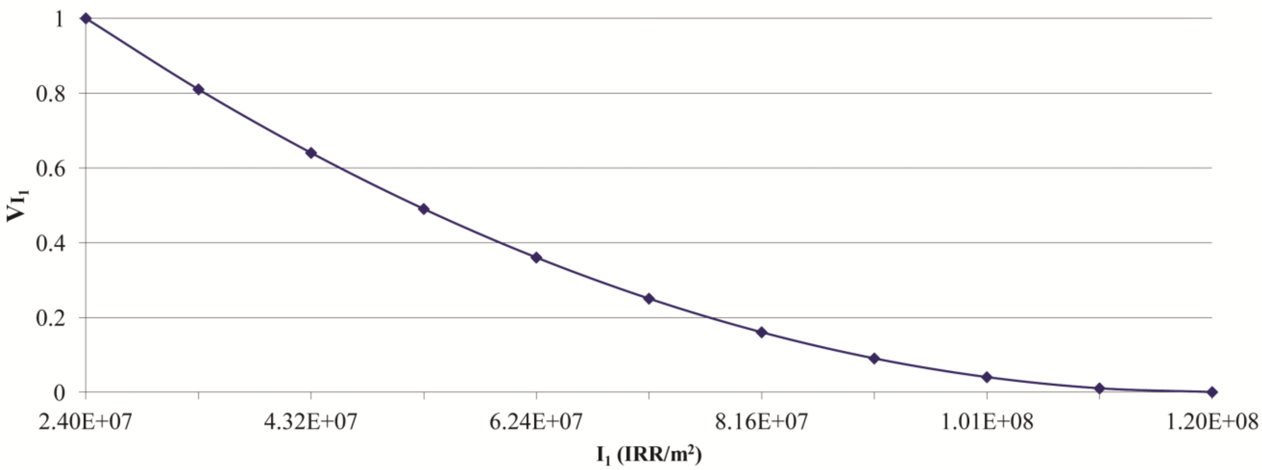

Fig. 7.5. Value function of the land price indicator (I_1)

Additionally, the alternative approach used herein to address the assessment of the weights is presented in the results and discussion section. This approach does not depend on the priorities of the experts. The assigned weights are based on choosing a site during a pre-disaster normal situation. These weights should be considered when this model is applied after the disaster.

Finally, by having each index value function (V_{x_k}) and its weight(λ_k), which have previously been explained, equation (4) can be applied for each level of the tree. Fig. 7.3 shows the mentioned process to obtain the sustainability index.

7.7. Results and discussion

The results from this evaluation are the sustainability index (I), requirement values (V_{R_k}), criteria values ($V_{\mathrm{C_k}}$), and indicator values ($V_{\mathrm{I_k}}$) for each alternative, as shown in Table 7.5. As Table 7.5 shows, the maximum sustainability index score I of the site location for TH is 0.61. Additionally, there are indicators and criteria that only change due to the site characteristics, irrespective of the site location, such as I_5, I_6, and I_8. For instance, I_6 is only related to land use and ownership.

Table 7.3. Parameters and coefficients for each sub-indicator value function.

I_x	Sub-Indicator	Unit	X_{max}	X_{min}	C	K	P	shape	References
I_3	Access of DP	Pts.	1	0	0.3	0.2	3	(IS)	Atlas of Teheran Metropolis
	Access to Emergency Services	min.	20	4	9.2	0.8	3.4	(DS)	Alavi et al. 2013; It's About Time: Why emergency response times matter to firefighters and the public 2010; Lee 2012
I_7	Density	pers./Ha	349	9	360	0.05	2.5	(DCx)	Atlas of Teheran Metropolis; JICA 2000; Mohammadzade Asl et al. 2010
	Hospital	pop./N Hosp.	180,000	50,000	220,000	0.5	4	(DCx)	Atlas of Teheran Metropolis; JICA 2000; Mohammadzade Asl et al. 2010
	School	pop./N Sch.	2,100	200	2,150	0.05	3	(DCx)	Atlas of Teheran Metropolis; JICA 2000; Mohammadzade Asl et al. 2010
	Green Area	m^2/pop	20	2	13	0.15	6	(ICx)	Atlas of Teheran Metropolis; JICA 2000; Mohammadzade Asl et al. 2010; zayyari et al. 2012
	Police	pop./N P.S.	14,000	1,300	15,000	1	3	(DCx)	Atlas of Teheran Metropolis; JICA 2000; Mohammadzade Asl et al. 2010
	Fire Station	pop./ N F.S.	300,000	10,000	400,000	1	3	(DCx)	It's About Time 2010; Alavi et al. 2013; Structure Fire Response Times 2006

Some indicators are influenced by the site location, such as I_2, I_3, I_4, I_7, and I_9. The sites that are located near the city centre obtain high satisfaction values in accessibility (I_3) and population cover (I_4). The sites that are located on the outskirts of the city have an adequate density and green area, are usually close to resources and main roads, and usually have lower land prices. Thus, these sites have higher satisfaction values for the following indicators: land price (I_1), neighbourhood acceptability (I_7), and emissions (I_9). Additionally, alternatives that consist of some sets, such as B and C, obtain maximum satisfaction according to access (I_3) and population cover (I_4) and minimum satisfaction from the cost of site preparation (I_2).

Table 7.4. Requirements tree with weight assignments.

Requirements	Criteria	Indicators
R_1. Economic (45%)	C_1. Invest Capital (100%)	I_1. Land Price (75%)
		I_2. Cost of site preparation (25%)
R_2. Social (25%)	C_2.User Safety (80%)	I_3. Access (30%)
		I_4. Population Covering (20%)
		I_5. Distance from Source of Danger (50%)
	C_3.Flexibility (20%)	I_6. Property and Land Use Zoning (60%)
		I_7. Neighbourhood Acceptability (40%)
R_3. Environmental (30%)	C_4. Land use (25%)	I_8. Landscape Respect (100%)
	C_5. Emissions (75%)	I_9. CO_2 Emission (100%)

In general, sets B and C have minimum values for economic requirements, and these sets and A_2 have high values for social requirements. Alternatives A_1 and A_4, which are located out of town, have maximum values for the environmental requirement. Alternative A_1 has the maximum value for economic requirements. A_1 is the most sustainable alternative site for post-disaster TH among the alternatives assessed, as shown in Table 7.5 and Fig. 7.6.

Moreover, the sites that have been provided for other functions and have facilities, such as C_{12} (parking lot) and C_{14} (barracks), obtain high sustainability values. Moreover, the sites that are located on the outskirts of the city obtained high environmental index values because they are close to resources and main roads; there are no landscape vulnerabilities greater than the other alternatives. Sixteen different scenarios have been considered to determine the sustainability index trends for the alternatives when the requirement ratios were different, as shown in Fig. 7.7. The highlighted point on the horizontal axis (economic 45%, social 25%, and environmental 30%) shows the sustainability indexes of technologies based on suitable weights chosen by the experts. If the environmental weight increases compared to the social weight, such as the first point on the horizontal axis in Fig. 7.7 (economic 47%, social 18%, and environmental 35%), A_1 becomes a more sustainable alternative. If the economic weight increases, such as the fifth point on the horizontal axis in Fig. 7.7 (economic 50%, social 25%, and environmental 25%), A_1 becomes a more sustainable alternative again. If the social requirement weight increases, A_2, C, and A_1 will be suitable alternatives, although the economic and environmental requirement weights can qualify A_1 as a final result.

Table 7.5. Sustainability index (I), requirements (V_{R_k}), criteria (V_{C_k}), and indicators (V_{I_k}) values for the six alternative sites

Alternative	I	V_{R1}	V_{R2}	V_{R3}	V_{C1}	V_{C2}	V_{C3}	V_{C4}	V_{C5}	V_{I1}	V_{I2}	V_{I3}	V_{I4}	V_{I5}	V_{I6}	V_{I7}	V_{I8}	V_{I9}
A_1	0.61	0.59	0.50	0.73	0.59	0.37	1.00	0.50	0.80	0.56	0.68	0.78	0.60	0.03	1.00	1.00	0.50	0.80
A_2	0.55	0.47	0.92	0.35	0.47	0.92	0.91	0.50	0.30	0.46	0.52	0.82	0.88	1.00	1.00	0.79	0.50	0.30
A_3	0.37	0.18	0.46	0.58	0.18	0.41	0.68	0.50	0.61	0.02	0.67	0.59	0.98	0.07	1.00	0.19	0.50	0.61
A_4	0.52	0.28	0.49	0.91	0.28	0.41	0.82	0.75	0.96	0.13	0.72	0.72	0.88	0.03	1.00	0.54	0.75	0.96
B	0.43	0.13	0.78	0.60	0.13	0.79	0.75	0.58	0.61	0.05	0.36	0.99	0.98	0.59	1.00	0.36	0.58	0.61
C	0.47	0.09	0.93	0.65	0.09	0.99	0.72	0.73	0.62	0.11	0.02	0.98	0.98	0.99	1.00	0.31	0.73	0.62

Therefore, if the quality of life of DP was the first priority for decision-makers, A_2 and C could be suitable alternatives. However, A_1 has a high sustainability value that is based on suitable weights chosen in the seminars and the economic requirement to a greater degree than the other alternatives. Additionally, the trend of the A_1 sustainability index did not change drastically when considering different requirement weights. A_3, A_4, and B obtain lower sustainability values compared to the other alternatives under all of the conditions assessed.

In the end, the results obtained by the MIVES method have been compared with several techniques to consider the validation of the model results. To this end, the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) (Hwang and Yoon 1981), ELimination Et Choix Traduisant la REalité: Elimination and Choice Expressing Reality (ELECTRE) (Roy 1968), and Simple Additive Weighting (SAW) have been used. Additionally, Shannon's entropy (SE) has been applied to evaluate the weights of the indicators. The weights of the indicators have been obtained by Shannon's entropy based on two approaches: (1) with regard to the weights assigned to the indicators based on expert judgment (SE/W) and (2) without regard to the weights assigned to the indicators (SE/NW). Therefore, six models, including three techniques (TOPSIS, ELECTRE, and SAW) with two weight assignment techniques (SE/NW and SE/W), have been considered. Additionally, the MIVES method has been considered according to the weights of the indicators, which were obtained by Shannon's entropy without consideration of the indicator priorities (SE/NW), except the suitable weights chosen by the experts.

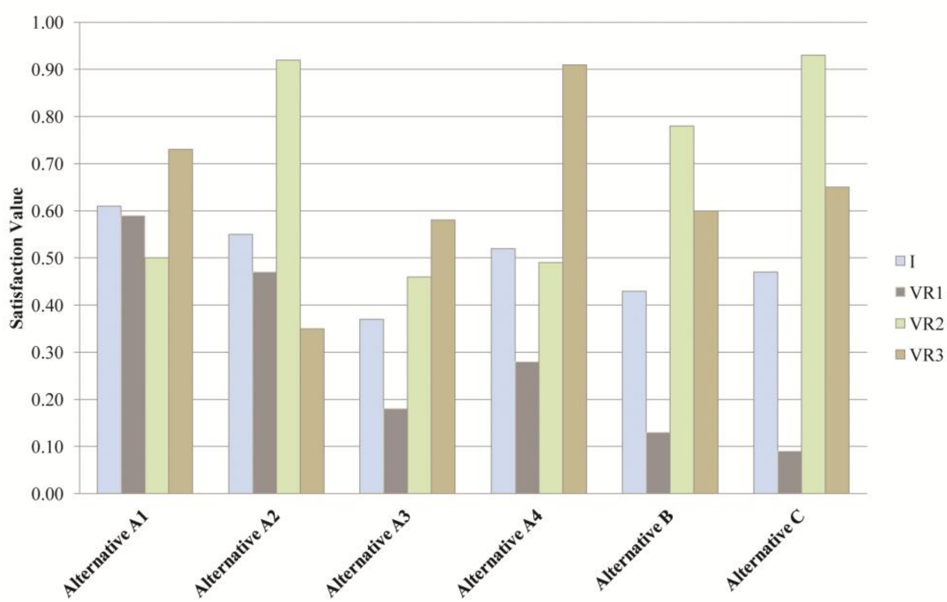

Fig. 7.6. Sustainability index (I) and requirement values (V_i) for the six alternatives

Table 7.6 presents the ranking of the alternatives obtained from the various methods. Obviously, different methods provide diverse results, although the results are almost the same for the ranking of four alternatives. A_1, A_3, B, and C are ranked as the first, sixth, fifth, and fourth alternatives, respectively, based on the results of at least six techniques among eight. Although the four alternatives have been presented in the second rank by the methods, A_2 has been selected more than the other alternatives.

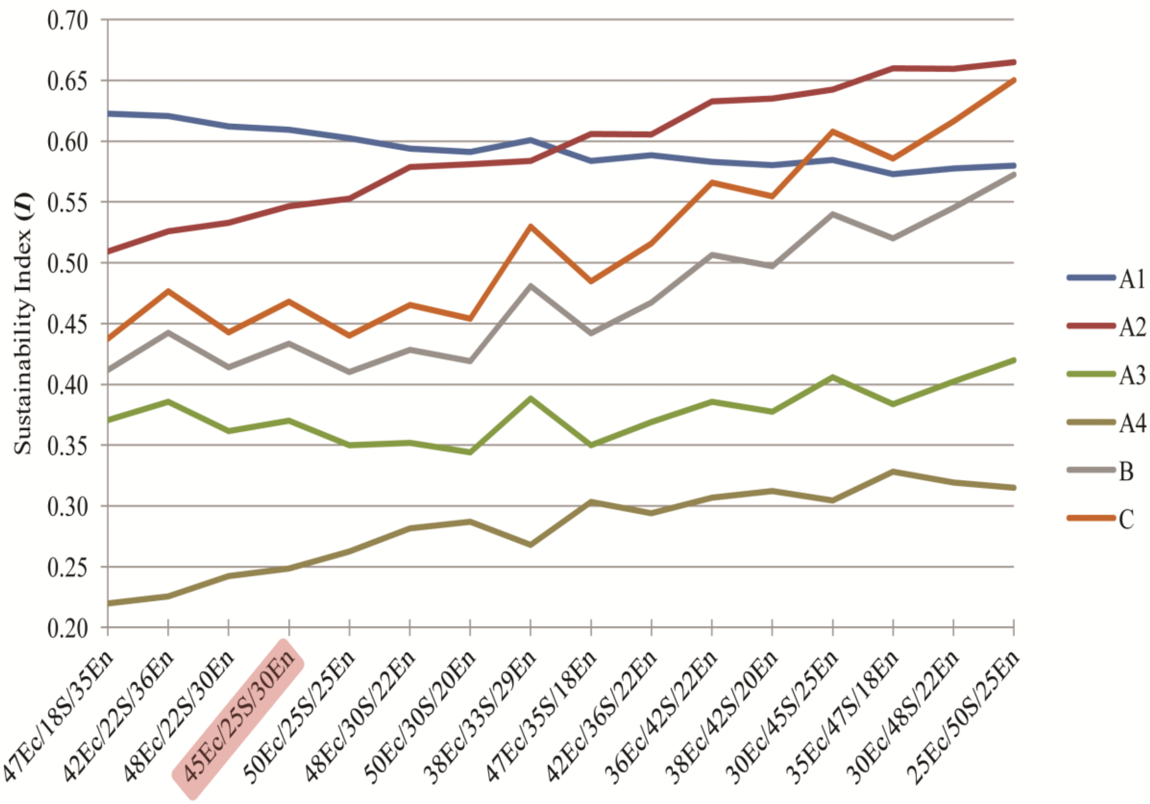

Fig. 7.7. Sustainability indexes of the six alternatives with different requirement weights (economic (Ec), social (S), and environmental (En))

Additionally, A_4 has been chosen more of than A_2 for the third rank by the methods. Therefore, the results provided by the proposed techniques qualify the model presented by this study. However, the differences between MIVES and the results of the other methods are understandable because this model incorporates the concept of the value function, which is necessary for TH consideration.

Table 7.6. The ranking of alternatives based on the methods

Method / Ranking	MIVES (AHP)	MIVES (SE/NW)	TOPSIS (SE/NW)	TOPSIS (SE/W)	ELECTRE (SE/NW)	ELECTRE (SE/W)	SAW (SE/NW)	SAW (SE/W)	Total Result
1	**A_1**	A_2	A_2	A_1	A_1	A_1	A_1	A_1	A_1
2	**A_2**	A_1	A_1	C	A_2	A_2	A_4	A_4	A_2
3	**A_4**	A_4	A_4	A_2	A_4	A_4	A_2	A_2	A_4
4	**C**	C	A_3	A_4	C	C	C	C	C
5	**B**	B	B	A_3	B	B	B	B	B
6	**A_3**	A_3	C	B	A_3	A_3	A_3	A_3	A_3

7.8. Conclusions

In this research, a new sustainability assessment model, which has been specifically configured to analyse alternative sites for temporary post-disaster settlements in urban areas, has been presented. For the application example, a total of six different alternatives for temporary housing have been assessed, which include 23 different sites in Tehran. This model takes into account the following aspects: maximizing the well-being of the DP, minimizing the negative impacts on neighbourhood life, minimizing the public expenditures on TH, minimizing the negative environmental impacts, and maximizing the well-being of the people involved in the TH process. The following conclusions can be derived from this research:

- This study defines an assessment model based on the MIVES methodology, which has been demonstrated to be a suitable strategy to conduct multi-criteria decision processes for an integral sustainability analysis of each alternative.
- This model is capable of comparing alternatives without being limited by the present conjuncture. In consequence, this tool is capable of adapting its parameters (cost, methods, access, etc.), which change from one period of time to another. Additionally, this model has the ability to be used for distinct cities by reconsidering the requirement tree weights.
- During the site selection process, this model assists decision-makers in observing and comparing the index values of all alternatives. Sometimes, decision-makers choose alternatives that have weaknesses that are caused by limitations; based on

the aforementioned feature of this model, decision-makers can detect the weak parts of a specific site and then overcome these weaknesses with proper actions.

- Diffuse sites located in different districts have the best social index value. Indeed, these sites can give higher satisfaction to DP, involving labour and neighbours. However, these sites have lower economic and environmental index values. Moreover, these disperse sets can cause increased transportation and individual mobilization, and they are usually located at greater distances from resources. Consequently, they cause increases in expenses and environmental damages.
- Sites that had other functions prior to selection and already had facilities have higher sustainability indices.

The model and the requirements tree proposed in this study are generic for any site location of post-disaster TH. However, some indicators and weights should be adjusted according to the specific analysis of site selection for other public functions, such as public facilities, educational services, health services, and so on.

Chapter 8

A Combination of Knapsack Algorithm and MIVES for Choosing Optimal Complex of Temporary Housing Sites Location

8.1. Introduction

Site selection is a process that involves many steps from planning to construction, including initial inventory, alternative analysis, assessment, detailed design, and construction procedures and services (kelly 2010). This process becomes more complicated issue with noteworthy outcomes, when decision-makers are forced to choose site location of temporary housing units (THUs) in the wake of natural disasters under emergency situations and external pressures. The site selection problem is multiplied because of moving DP from the previous properties, communities, and activities (Building Regulations 2010; Johnson 2002), beside emergencies. Additionally, according to (El-Anwar et al. 2009a; Johnson et al. 2006; Lizarralde et al. 2009), the reason of TH delay is due to obtain the safest areas for TH among the potential lands. In this regard, Johnson (2007a) stated that the site location for TH could have a considerable impact on public expenditures, beside environmental impacts. Meanwhile, Hidayat & Egbu (2010) stated that determining suitable location for reside DP is common problems of this issue. Furthermore, site selection of THUs could cause more negative economic impacts, if THUs, which have been erected for DP, are rejected due to unsuitable site location, such as the Bam, Iran, and Pescomaggiore, Italy, cases (Fois & Forino 2014; Ghafory-Ashtiany & Hosseini 2008).

In general, according to (Hadafi & Fallahi 2010; Hosseini et al. 2016a; Johnson 2007a; Kelly, 2010; Quarantelli 1995), improper site location of THUs could lead to some problems as following: (1) late delivery time, (2) secondary hazards, (3) expenses, (4) losing previous communities, (5) effects on host community, and (6) environmental pollutions. However, decision-makers cannot conceal this approach, which was applied for many recovery programs during last decades, because of some local limitations and THU benefits: (1) deficiency of other alternatives, (2) huge amount of demands, (3) immediacy (4) climate conditions, (5) DP pressure, (6) DP reluctances, (7) short-delivery, and (8) high quality. Therefore, site location, which seems ordinary factor, has considerable impacts on failing recovery program and DP´s satisfactions. Meanwhile, this could be more serious challenge due to the increase of urban population (UN 2014), especially growth of population who lives in areas prone to natural disasters (Lall & Deichmann 2009), informal settlements (Johnson et al. 2006), change of natural disasters (Field 2012), and other limitations of areas, such as land scarcity, and increase of world wild concerns about environmental sustainability. Thus, to deal with this issue with a representative amount of stakeholders requires considering all aspects for selecting suitable ones to decrease negative impacts. Meanwhile, THUs provision could not be concealed due to natural disasters, which happen again, and local requirements. Therefore, in order to find out a suitable solution for this problem among available sites is required to choose a most sustainable subset based on demanded factors. However, this fact could be complicated process for decision-makers due to intricacy of multifaceted site selection issue, wide range of possible alternatives, and amount of diverse stakeholders.

This study aims at presenting suitable avenue to come up with a sustainable solution of site selection. Indeed, this provides a platform to assist decision-makers to determine most sustainable alternatives among wide range of possibilities. Meanwhile, the diverse experts and engineers are required to take part in decision-making process of site location selection. In this regard, this research provides the response to decision-makers needs to a set of sites, whose total area is equal or close to the required area, which is determined based on number of DP and person per capita. However, it is possible that total areas of many (huge amount of) subsets, which include initial acceptable alternatives, are equal or close to demanded area for TH sites. In this case, a model is required to specify appropriate subsets among all. Thus, this problem could be addressed in two phases: (1) determination of clusters with regard to the required area, and (2) select most proper subset in terms of sustainability. To this end, the combination of Knapsack algorithm and MIVES method is used to reach at sustainability solutions.

According to Martello & Toth (1990), the Knapsack algorithm is used for having a set of alternatives based on specific values and size. This selects one set or more sets, whose members' total size are equal or less than demanded size whilst, the sum of the chosen values is maximum. In this research project, the size is total demanded area and the value is attributed to the sustainability index (SI), which is evaluated by MIVES, the Integrated Value Model for Sustainable Assessment. MIVES is a MCDM that embraces the concept of a value function based on the utility theory. The advantage of MIVES compared to other MCDMs for TH management is that this: (1) is independent of the time; (2) can be applied for diverse areas with different local characteristics and requirements, and (3) can consider all stakeholders' satisfactions and necessities by adjusting the requirements tree´s members and weights in simplicity way (Pons et al. 2016).

The new model presented in this research paper is applied to determine the best site location for TH in the case of a probabilistic earthquake of Mosha's fault in Tehran (Iran) which is expected to occur if according to the report of Japan International Cooperation Agency (JICA) and the Centre for Earthquake and Environmental Studies of Tehran (CEST) (JICA, 2000). This model has been designed for choosing site location of TH before these natural disasters occur. However, this model could also be used after natural disaster after carrying out a few modifications.

8.2. Methodology

This study is broken down into two phases: (1) *data gathering phase*, to define site selection requirements and sustainability factors. This section is conducted based on primary and secondary sources of previous recovery programs, and (2) *operation phase* in which the solution selection is performed by using sustainability concepts, as shown in Fig. 8.1. This process is dealt with the MIVES-Knapsack algorithm.

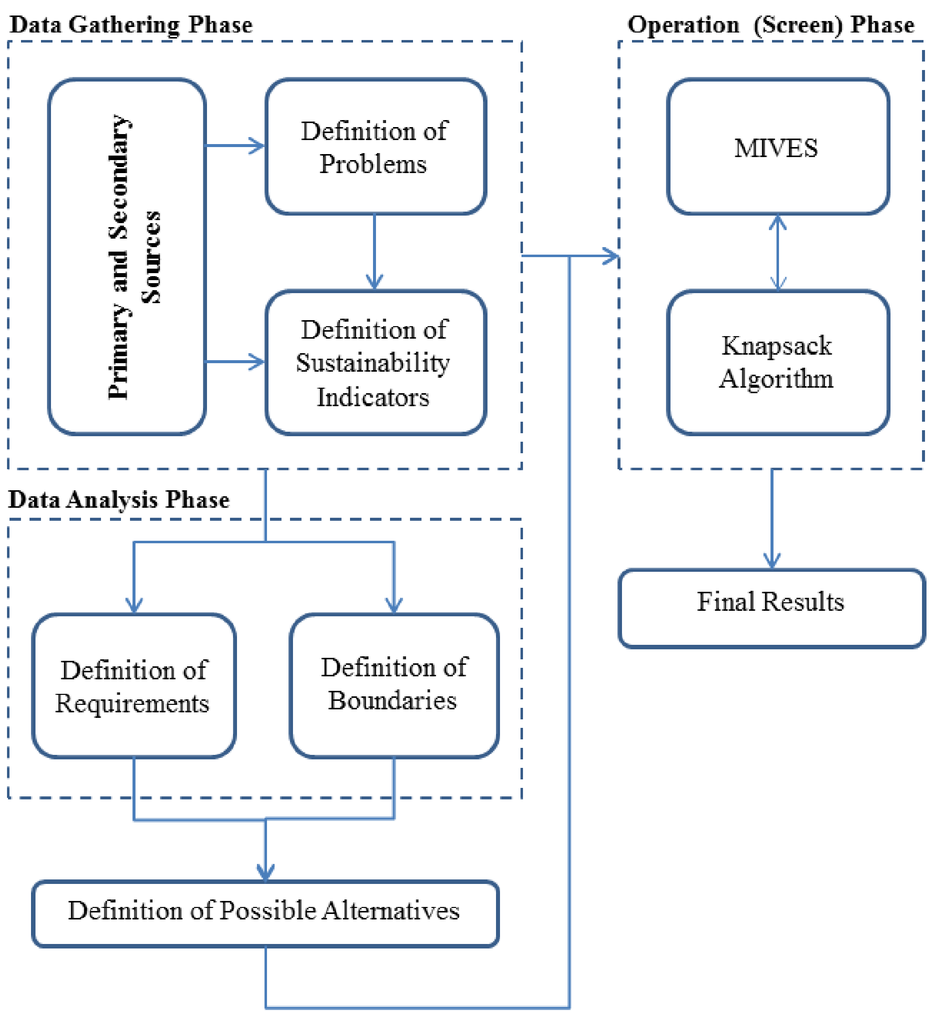

Fig. 8.1. Approach proposed for sustainable site selection based on coupling MIVES-Knapsack method

In the first phase, a problem is generally considered to define sustainability indicators based previous researches and recovery programs. Then according to local characteristics and requirements, possible alternatives are determined based on current potentials and natural hazards. Indeed, problem data, including demanded area, sustainability requirements, potential sites, and consequently, all possible or acceptable sites for the initial alternative set are specified in this stage. In the next stage, subsets are selected if the subsets embrace two conditions: (1) total areas of sites in each subset are located (assigned) in demanded range, and (2) subsets achieve highest SIs. Therefore, in this model, MIVES is used as the sustainability assessment tool to evaluate SI of each alternative site and consequently, SI of each chosen subset. Meanwhile, Knapsack is applied as the operational tool to determine optimized subsets based on first and second conditions. Additionally, Knapsack introduced in C^{++} software by using dynamic programing to reduce operation time. Indeed, each subset could be chosen by the designed model, if equation (8.1) is established.

$$W_1 \leq \sum_1^i A_n \leq W_2 \tag{8.1}$$

$$\text{Maximize} \quad \frac{\sum_1^i SI_n * A_n}{\sum_1^i A_n}$$

A_i : Area of site *i*

W_1 , W_2 : Minimum and maximum demanded area

i : Number of subset´s members

SI_n : Sustainability index of site *n*

8.2.1. MIVES method

In order to obtain SI of each subset, geometric mean of SIs of sites in each subset (group) is calculated. SI of each site results from using MIVES, following the steps: (1) designing a requirements tree, (2) specification of minimum (X_{min}) and maximum (X_{max}) satisfactions for each indicator, (3) tendency and shape of value function determination, (4) weighting of indexes, and (5) apply formula of MIVES.

This study uses two approaches in order to determine the indexes' weights: (1) evaluating the weights by a group of multidisciplinary experts using Analytical Hierarchy Process (AHP) (Saaty 1990), and (2) Shannon's entropy (SE) with and without regard to the weights assigned by expert judgment. Furthermore, according to (Alarcon et al. 2011), the function of each indicator could have four diverse shapes (concave, convex, linear, and S-shaped), beside decreasing or increasing trends. There are complete explanations about the MIVES methodology in previous studies, such as Alarcon et al., 2011; Aguado et al., 2012; Cuadrado et al., 2015.

8.3. Sustainability assessment model with MIVES

According to (Alexander 2004; El-Anwar et al. 2009b; Hosseini et al. 2016b; Hui 2012; Kelly 2010; Nojavan & Omidvar 2013; Omidvar et al. 2013), site selection problem, requirements, and consequently indicators have been derived. However, the indexes have been adjusted based on the chosen case study by interview with local experts. As a result of this process, the resulting requirements tree imposing the independency of both the indicators and the time is presented in Fig. 7.3. Three different requirements (economic, social, and environmental) have been established in the first level of the three.

In the economic requirement (R_1) total expenses for TH site are included. The social requirement (R_2) has been included in order to assess aspects related to user's safety and flexibility of sites. The environmental requirement (R_3) is considering aiming at taking into account the environmental impacts of site selection during whole life cycle of TH. The second hierarchical level of the tree is formed by the five criteria and the third level includes nine indicators. While the requirements and criteria are not quantifiable, the indicators are measurable.

The first criterion, *invest capital* (C_1) embraces two indicators: (I_1) *land price*, in which the cost of land (cost/m^2) is considered. (I_2) *cost of site preparation*, which embraces costs of all activities for site preparation: mobilization, levelling, utilities and so on. A special attention should be paid to sites with existing utilities and facilities. In this regard, the δ factor presents the quality of the utilities and facilities aftermath of the natural disaster based on experts' prediction.

The second criterion, *user safety* (C_2), includes the three indicators: (I_3) *access*, through which site accessibility, in terms of emergency services and DP, is taken into consideration. As the DP access immediacy is considerably lower than emergency services access, only the latter is considered. Additionally, the quality of emergency services is treated as a sub-indicator of neighbourhood acceptance. (I_4) *population covering*, which prevents from decentralization of alternative site and more coverage based on DP distributions. This indicator can be assessed by means the use of equation (7.1). (I_5) *distance from sources of danger* takes into account potential dangers to avoid happening secondary hazards by considering two factors: (1) distances from source of dangers and (2) quality or intensity of dangers.

Flexibility (C_3), comprises two indicators: (I_6) *property and land use zoning*, which assesses alternative sites in terms of ownership situations and land use. (I_7) *neighbourhood accessibility* includes the six sub-indicators (density, green areas, schools, police, hospitals, and fire services of the demanded areas) with which potentials of host area for adding DP and impacts on host community are assessed.

The fourth criterion, *land use* (C_4), includes (I_8) land *use respe*ct indicator, which takes into account site location effects in terms of ecosystem change. The fifth criterion, *emissions* (C_5) embraces (I_9) CO_2 emission expressed in terms of equivalent CO_2 emissions (Intergovernmental Panel on Climate Change (IPCC) 1996) associated to all those required activities, including transport, for site preparation.

8.4. Case study (Earthquake in Tehran)

8.4.1. Relevant data

This study considers four districts of Tehran, capital of Iran, aftermath of probabilistic earthquake based on the Mosha fault scenario. The data is derived from reports prepared by the Japan International Cooperation Agency (JICA) with the Centre for Earthquake and Environmental Studies of Tehran (CEST), as shown in Table 7.1. This report presents casualties and damaged buildings in the wake of probabilistic earthquakes based on four different scenarios: the Rey, the Mosha, the North of Tehran fault models, and the floating model (Omidvar et al. 2013). This research is intended to find out sustainable subsets of alternative sites with regard to results for the Mosha fault model by the JICA and CEST based on the approach proposed.

According to the JICA and CEST study (2000), a probabilistic earthquake during the day could lead to more than 610,000 DP and almost 18,000 casualties. The estimated DP of the four districts exceeds 160,000 people. This implies that all required sites should have capacity for residing one-third of DP whilst other types of TH can be used for the two-third of the DP. Additionally, in order to increase both number of alternatives and potential subsets to make more difficult problem, it is assumed that some sites are located outside the city centre, close to entry roads. Thus, the half of the DP is settled in these camp sites in outside of city centre and consequently, the alternative sites, which are located in city centre should reside the remained DP, half of all. Therefore, the total area demanded is nearly 50 hectares based on 20 square meters per person. However, the required area for each person has been considered 30 and 45 m^2/pers. Meanwhile, this study has obtained a required area of almost 20 for each person based on land scarcity in Tehran and possibility of multi-story THUs.

The possible alternative sites with the intended initial features are selected with regard to the defined sustainability requirements. There are nineteen alternative sites (S_1-S_{19}) located in four districts and a district near these, as shown in Fig. 8.2. Areas of the chosen sites are diverse from 2.3 to 40.0 ha. All these sites need to prepared before use, except S_{17} (parking lot) and S_{19} (barracks).

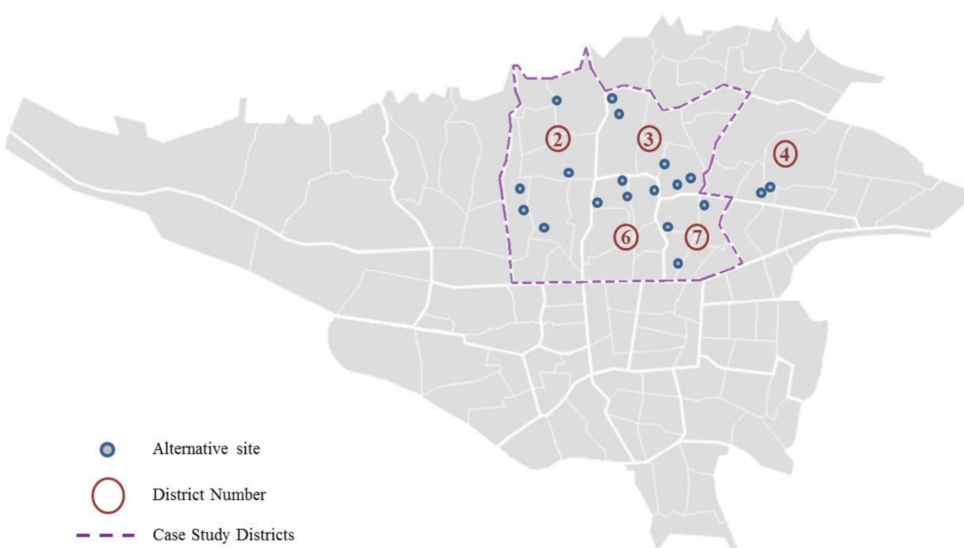

Fig. 8.2. Tehran map (including the case study districts and alternative sites)

8.5. Analysis

With the objective of assessing the SI of subsets (with total area close to demanded 50 ha) is required to consider. Value functions and the boundaries of indicators (X_{min} and X_{max}) have been established (Tables 7.2 and 7.3) considering information from the scientific literature, international guidelines, Iranian principles, and knowledge of experts´ seminars. The value functions are formed based on following shapes: four decrease, of which two decrease in a convex manner (DCx) and two decrease in a concave manner (DCv), and five increase, of which two are increase in a convex manner (ICx) and three S-shaped (IS).

For some indicators (I_3, I_6, I_7, and I_8) points assignments system have been applied. Additionally, it should be emphasized that weights of the sub-indicators are considered same for *neighbourhood acceptability* indicator (I_7).

8.5.1. Weight assignment

The weights were assigned by using two approaches: (1) experts judgment, which is named AHP as the abbreviation because this approach is based on MIVES concept by using AHP, and (2) Shannon's entropy (SE). The weights (λ_i), see Table 8.1, were determined by carrying out meetings and seminars held by professors of the Universitat Politècnica de Catalunya (UPC), Universitat Internacional de Catalunya (UIC), Tehran Disaster Mitigation and Management Organization, and the experts of the Tehran Disaster Mitigation and Management Organization. In this regard, coefficients of variation of each λ_i did not exceed 10%, excluding the outliers that were eliminated.

Additionally, in order to verify the adequacy the model and minimizing source of errors (bias, for instance) during weighting distribution, these were previously estimated by Shannon's entropy based on two approaches: (1) considering the indicators weights assigned by experts (SE/AHP) and (2) without considering the weights proposed by the experts (SE/NW).

These results were analysed following two different strategies: (1) consideration of indicators' values (V_i) derived from using each weighting technique, and (2) change of the requirements weights (sensitivity analysis). By doing this, the indicators' values (V_i) and SI values of the optimal subsets presented in Table 8.1 were reassessed using the other two weighting techniques (Table 8.3 and Fig. 8.3). That is SI of the subset A is determined also with the of SE/AHP and SE/NW weighting techniques.

In view of the results gathered in Tables 8.1 and 8.2, it can be stated that the resulting subsets are consistent with both model and weighting criteria. For instance, SI of the subset A is 0.52 whilst, SIs of the subsets B and C are 0.41 and 0.37, respectively, provided that AHP is used. The same trend is confirmed for the other subsets and weighting approaches.

Finally, it is possible to assess SI of each alternative site by having each index value function (V_i) and its weight (λ_i) and using equation (2) for each level of the requirements tree (Fig. 7.3). Thus, in this step, it is necessary to apply designed MIVES-Knapsack coupled algorithm to determine sustainability subsets, whose total areas of members are close to the 50 ha and maximize SI (equation 1). It must be highlighted that solutions with total area up to 55 ha (10% above the 50 ha the required) have also been assumed as acceptable in order to find out more possible results and for further analysis.

Table 8.1. Weight assignments of indexes based on the experts judgments

Requirements	Criteria	Indicators
R_1. Economic (45%)	C_1. Invest Capital (100%)	I_1. Land Price (75%)
		I_2. Cost of site preparation (25%)
R_2. Social (25%)	C_2.User Safety (60%)	I_3. Access (30%)
		I_4. Population Covering (20%)
		I_5. Distance from Source of Danger (50%)
	C_3.Flexibility (40%)	I_6. Property and Land Use Zoning (60%)
		I_7. Neighbourhood Acceptability (40%)
R_3. Environmental (30%)	C_4. Land use (25%)	I_8. Landscape Respect (100%)
	C_5. Emissions (75%)	I_9. CO_2 Emission (100%)

8.6. Results and discussion

The results obtained from applying the MIVES-Knapsack method and different assigned weighting approaches are shown in Table 8.2. The three different subsets presented in Table 8.2, have been obtained by the three diverse weighting techniques (AHP, SE/AHP, and SE/NW). The optimal alternatives resulting from the model confirm that wide range of feasible sites has been obtained. Consequently, the results need to be analysed rigorously to achieve a more suitable subset. Indeed, if there were more alternatives in a subset, such as the achieved subset by AHP, it could have a higher satisfaction level in terms of some social requirements, except for I_7, compared to other methods since AHP tends to assign lower weight for I_7. Additionally, some sites are common to almost all applied weighting techniques that confirm suitability of these alternatives, such as S_2, S_3, S_4, and S_{19}. The maximum SI has reached for the subset C (0.69, SE/NW), this being a 32.7% and a 15% higher than that obtained for subset A (0.52, AHP) and subset B (0.60, SE/AHP), respectively.

Table 8.2. Sustainable subsets resulted by algorithm based on diverse weight assignments

Subset	Methods	SI	Assigned Weights			Selected	Total Areas
			Ec.	Sc.	En.	Sites	(ha)
A	**AHP**	0.52	45%	25%	30%	S_2, S_4, S_5, S_6, S_{17}, S_{18}, S_{19}	50.5
B	**SE/AHP**	0.60	45%	25%	30%	S_3, S_4	53.0
C	**SE/NW**	0.69	-	-	-	S_2, S_3	50.0

The SIs of optimal subsets demonstrate that the subset C has highest SI, 0.69. The SIs of subsets B and A are ranked as the second and third ranges, respectively. Although, the SIs of the subsets have determined, it is required consider each indicator's partial sustainability index ($I_{SI,i} = \lambda_{R,i} \cdot \lambda_{CR,i} \cdot \lambda_{I,i} \cdot V_i$). To this end, the values of I_{SI} for each indicator and sub-indicator based on the three weighting techniques are presented in Fig. 8.3. In the legend of Fig. 8.3, the first term represents the weighting technique and the second term the subset. For instance, AHP (C) represents that AHP (45%Ec, 25%S, and 30%En) is the technique considered and C is the subset.

Table 8.3. Considering the obtained subsets by other methods

Subset	A	B	C	A	B	C	A	B	C
weights	AHP	AHP	AHP	SE/AHP	SE/AHP	SE/AHP	SE/NW	SE/NW	SE/NW
SI	0.52	0.41	0.37	0.56	0.60	0.55	0.49	0.66	0.69

The Fig. 7.10 confirms when the values functions of subsets are evaluated based on the AHP weights, AHP (A, B, and C), values of the four indicators of the subset A are higher than the other subsets and the three indicators' values are almost same for the techniques (I_1, I_5, I_8, and I_9). Subset B has higher values of I_2 and subset C obtains highest value of I_7. Meanwhile, these facts establish for all indicators' values of the subsets when the three techniques are applied.

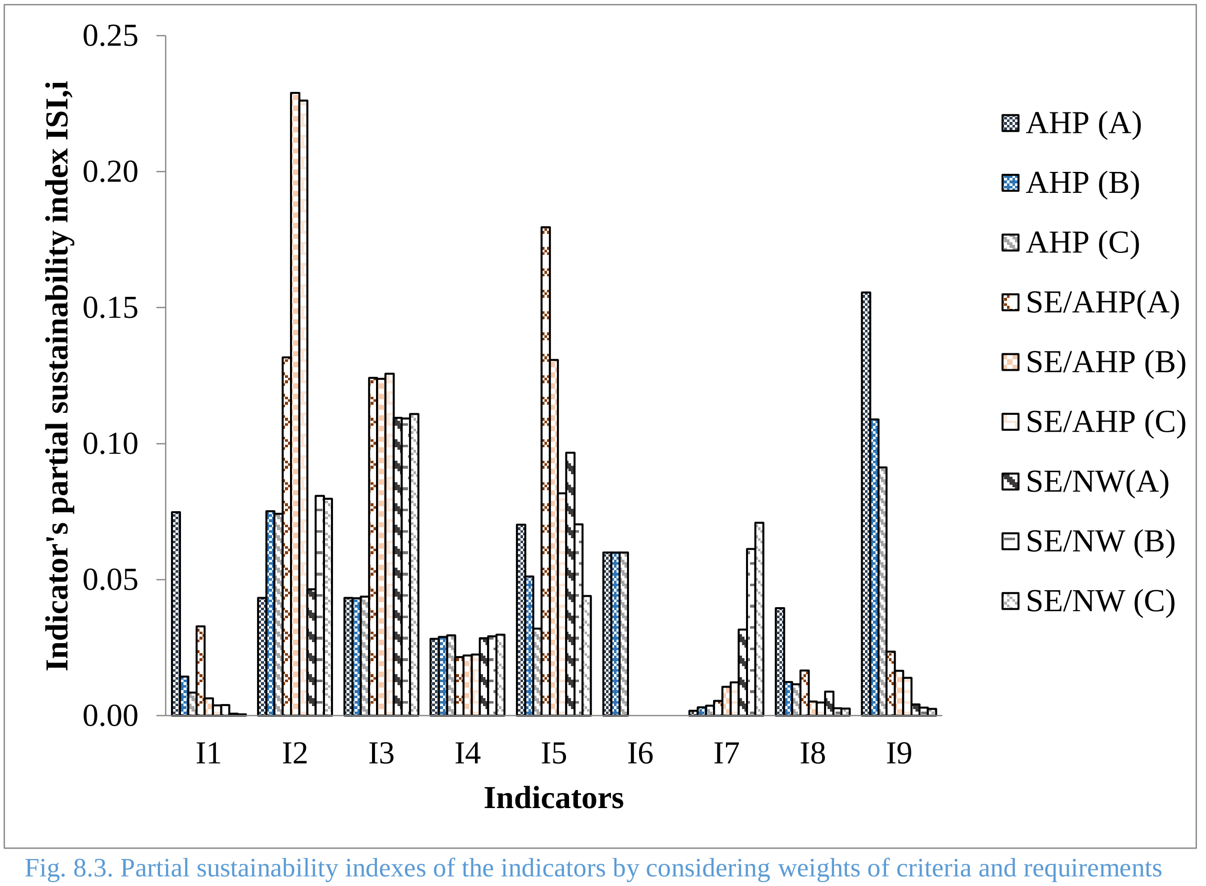

Fig. 8.3. Partial sustainability indexes of the indicators by considering weights of criteria and requirements based on applying the three methods for the optimal subsets

Fig. 8.4 presents the indicators' and sub-indicators' values (V_i). In this case, it is worth to note that no weights were applied. V_i can be understood as the satisfaction index associated to each indicator.

In terms of the *economic requirement*, the results gathered in Fig. 8.4 reveal that subset A presents the higher satisfaction for the land cost indication (I_1) and lower for site preparation costs (I_2) since five extra sites in comparison to subsets B and C are included within subset A. Subsets B and C results as the combination of areas S_3 (the highest in land area and price) however, S_2 and S_4 (both with minimum land price).

From this analysis, it could be concluded that two alternatives based on the economic requirement have resulted from applying the three weighting techniques. One the one hand, SE/AHP (subset B) and SE/NW (subset C) lead to a combination of two unique sites with high land prices and lowest site preparation cost whilst AHP (subset A) lead to a subset composed by several sites with minimum land prices and higher site preparation costs.

Regarding the *social requirement*, it can be noticed from the results presented in Fig. 8.4, indicators' I_3 and I_4 V_i values are rather independent of the subset configuration and, consequently, of the weighting criteria. Moreover, it can be observed that subset A obtains highest value for the indicators I_5 (43% and 150% higher than for subsets B and C) and I_6 (null satisfaction for subsets B and C); contrarily, subset A presents lower satisfaction of I_7. Finally, subset A presents the higher satisfaction in relation with the *environmental requirement* indicators.

The analysis of the results presented in Fig. 8.4 has led to conclude that each weighting technique, besides defining the optimal subset, also tend to favour a certain requirement. In other words, each selected subset has more considerable impact on each of the requirements according to the technique preference. For instance, using SE/NW (subset C) results in subsets with highest satisfaction values for I_7, since this technique assigns greater weights to the sub-indicators that from I_7 , as shown in Fig. 8.5. Contrarily, subset A presents higher value of I_1 because the AHP technique assigns high weights for the economic requirement and the associated indicators.

Therefore, weighting systems could have considerable impacts on the results. Nevertheless, all obtained subsets have maximum SIs compared to other feasible subsets. In this regard, it is highly recommended to assess weights of indicators by diverse techniques.

In this process, local experts should be involved in order to confirm results and to eliminate outliers.

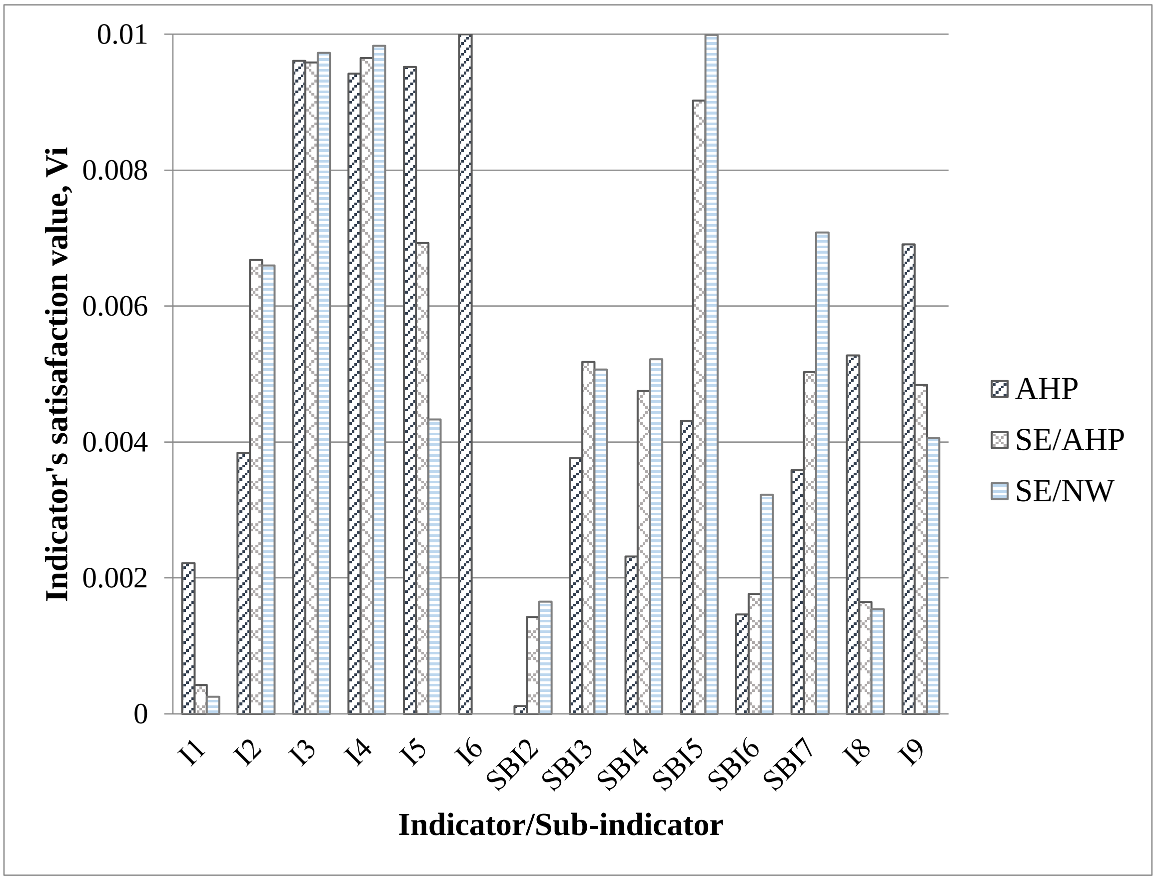

Fig. 8.4. Values functions of the indicators and sub-indicators without considering weights based on applying the three methods for the optimal subsets

Therefore, as the SE/NW system do not consider stakeholders' concerns, this method seems not to suit the TH´s paramount issues. Thus, it could be concluded that the results of AHP and SE/AHP are more reliable due to the consideration of the experts' judgments in both techniques. However, in this study the determined weights by the experts judgment needs to be modified slightly based on the obtained results, such as ratio of weights of I_1 and I_2. Nevertheless, in specific scenarios for which some requirements are more important and different from the present research the weights could be updated after following the same method. In general, the results confirm that subset A obtains high values of environmental and economic requirements. According to the indicators' satisfactions (Fig. 8.4), SE/AHP could be ranked after the AHP technique's results in terms of results reliability. The last option could be the SE/NW system, which considers more priorities for I_7. As, SE/NW has assigned high weights to I_7, no stakeholders' preference was considered.

A sensitive analysis for the AHP and SE/AHP methods considering twenty-eight requirements' weighting distributions has been carried out. To this end, a range comprising weights from 10% to 80% has been fixed by the experts'. This range even embrace outliers. As shown in Fig. 8.6, the AHP and SE/AHP techniques lead to different choosing frequencies for each site. In this regard, four alternatives sites (S_4, S_6, S_{17}, S_{19}) are elected more than the other sites by the AHP and SE/AHP techniques. Furthermore, subset A (S_2, S_4, S_5, S_6, S_{17}, S_{18}, and S_{19}) and B (S_3 and S_4) have resulted chosen by the AHP and SE/AHP techniques 23 and 13 times, respectively, from twenty-eight results for each technique.

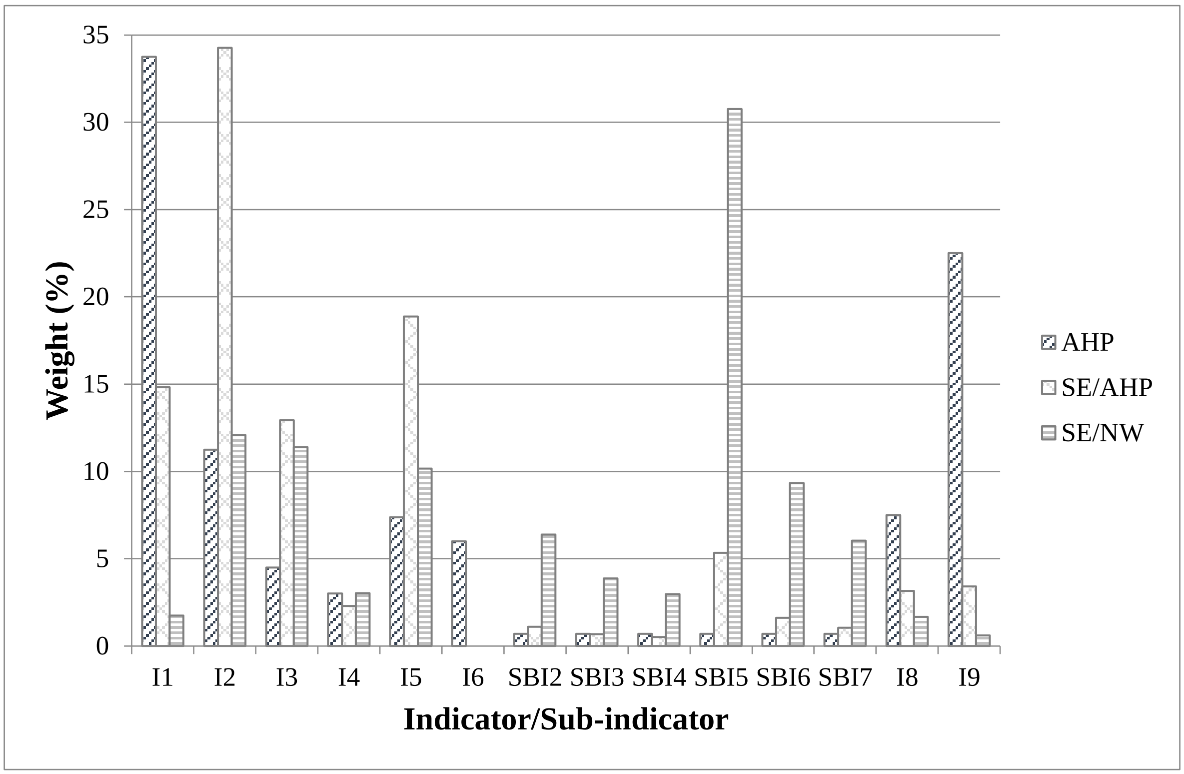

Fig. 8.5. Assigned weights to the indicators and sub-indicators by the three methods

S_{17} and S_{19} have minimum site preparation costs due to pre-disaster use as parking lot and barracks, respectively (see Annex). However, based on the minimum land prices of these two sites, it was expected that S_{17} and S_{19} are chosen as final alternatives. S_4 is ranked after S_{17} and S_{19} in terms of minimum land price. S_4 and S_6 could be categorized in a group of sites with high values of I_2; S_{17} and S_{19} being at the top. S_4 and S_6 have higher values of I_5 meanwhile; S_{17} is close to the middle range sites in terms of this indicator´s value. S_4 and S_6 obtain the second level of value of I_8, after S_{17} and S_{19}. Additionally, S_4 and S_6 have highest values of I_9; in this case, S_{17} is located in a group of sites with minimum values of I_9. In general, these four sites obtain acceptable satisfaction indexes of almost all indicators. Moreover, these four could generally be assigned to a group of alternative sites with highest economic and environmental indicators based on the identified weights by the experts.

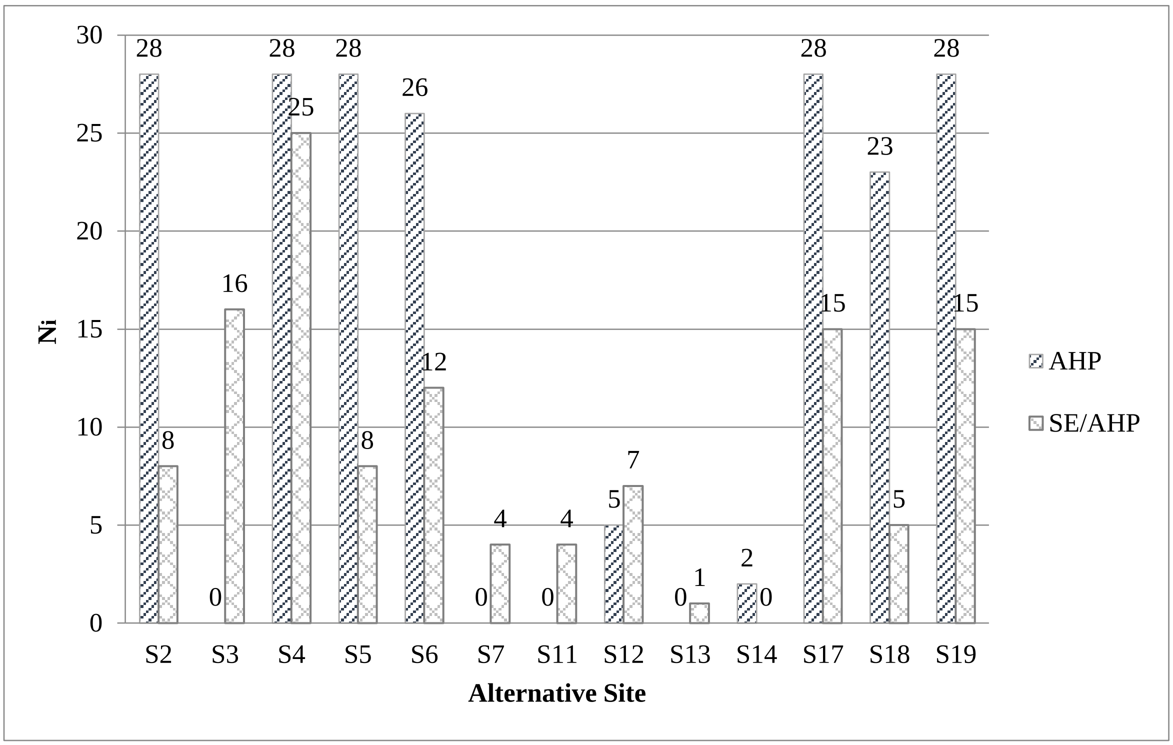

Fig. 8.6. Frequency of each site (N_i) depending on the weighting technique

As a conclusion derived from the analysis of the partial satisfaction indexes (Fig. 8.3) and the site selection frequency (Fig. 8.6), it can be stated that the MIVES-Knapsack proposed approach could be a robust decision-making model to deal with the configuration of post-disaster housing sites.

Fig. 7.17 presents trends of SIs based on the twenty-eight weighting scenarios. The results evidence that SIs increase when the weights of economic requirement decrease. This fact is a consequence of the low values of the economic indicators of all alternatives (see Fig. 8.4). However, it should be emphasized that the higher number of social indicators compared to the economic indicators (Y), is the reason of this increasing tendency of SI. In this regard, it can be deduced from the results that SI tends to decrease when the weight of the social requirement decreases, independently of the weighting technique. On the contrary, the lowest SIs are obtained when the highest weight is assigned to the economic requirement. This determines that SI has a direct relation with the social weights and an inverse relation with the economic weights.

Likewise, it can be observed SI trend are few sensitive to the variation of the environmental requirement weight. Finally, the results gathered in Fig. 8.7 reflect that SI values derived with both weighting techniques tend to converge as the economic requirement weight is reduced. Furthermore, only for the weighting distribution (10%Ec, 10%S, and 80%En), subset A (AHP) would be more sustainable than subset B (SE/AHP).

Fig. 8.7. Sustainability indexes of the chosen subsets by AHP and SE/AHP based on twenty-eight weights scenarios

8.7. Conclusions

A new MCDM model for dealing with the selection of TH site location based on local requirements has been proposed in this research paper. The model has been configured by coupling MIVES and Knapsack methods in synergistic form. On the other hand, the former allows assessing the sustainability index of each site alternative by minimizing economic and environmental impacts and maximize social aspects with regard to stakeholders' satisfactions. Furthermore, the model considers SI of the group of potential subsets that fulfils the demanded area solving a Knapsack algorithm. Weights were assessed resorting to different approaches: (1) experts' seminars and AHP following the MIVES strategy and (2) Shannon's entropy method. Furthermore, a sensitivity analysis of the results has also been carried out.

A case study consisting of an earthquake scenario in Teheran has been dealt with the proposed model. The obtained results are relevant for decision-makers in this specific case and, in general, these allow confirming that the model is useful, flexible and represents the stakeholders' needs involved in PD recovery programs. Therefore, it can be stated that the model has promising potential for future application related with site selection in areas prone to natural disasters. Additionally, the following conclusions could be derived from this study:

- The AHP procedure has led to the highest environmental indicators weights in comparison with the other two weighting approaches considered.
- In terms of economic aspects, there are two diverse strategies for selecting alternative sites based on this paper´s result: choosing high numbers of small-area sites with low land prices that leads to increase site preparation costs or, alternatively, various large-area sites with higher land prices that result in lower site preparation costs.
- As was expected and reported by other authors, the analysis of the results allows confirming that different weights' distribution have considerable impacts on the resulting subsets. Therefore, beside the weight assignment methods, it is crucial to consider stakeholders concerns when dealing with the TH management.

- It could be possible to achieve higher sustainability index, if the chosen subset includes sites, which have been already used for other functions.

This research paper has covered a specific field of the post-disaster TH management; however, in this same topic there are still aspects of paramount importance that should be treated as: the impact of number of indicators on the decision and, consequently, the value of the requirements.

Chapter 9

Multi-Criteria Decision-Making Method for Assessing the Sustainability of Post-Disaster Temporary Housing Units Technologies: A Case Study in Bam, 2003

9.1. Introduction

According to Global Estimates 2014, Twenty-two million people worldwide lost their homes to natural disasters in 2013. Additionally, in 2050, the population of areas highly prone to natural disasters is expected to be double that of 2009 for the same area (Lall &

Deichmann 2009). Furthermore the urban population will reach 66% of the world population by 2050 (UN 2014). Meanwhile, UN-habitat (2014) reported that in developing countries, one third of the urban population lives in slums that are highly vulnerable in terms of temporary housing (TH) provision (Johnson et al. 2006).

DP need somewhere to live in secure and sanitary conditions, and to return to normal life as before the disaster while their permanent houses are reconstructed; this is called TH (Collins et al. 2010; Davis 1978; United Nations Disaster Relief Organization (UNDRO) 1982). TH has generally been criticized due to the lack of sensibility towards an integrated view of sustainability, especially regarding the THUs.

THUs which need to be constructed after natural disasters are often categorized as a camp (United Nations High Commissioner for Refugees (UNHCR) 1999), grouped in planned camps (Corsellis & Vitale 2005), organized in a top-down approach (Johnson 2007a). According to Félix et al. (2013), THUs consist of (1) ready-made units and (2) supply kits. Although a THU is often conceived as a precast system (Johnson 2009), on-site masonry construction was used in previous TH programs.

The problems of the THU as a commonly used type of TH can be: (1) delays, (2) lack of fit with the culture of the DP, (3) the need for large public expenditures, (4) consumption of resources and investment assigned to permanent buildings, (5) permanent building reconstruction delays, (6) discordant durability of used materials and usage time, (7) site development process requirements, (8) site pollution, (9) infrastructure needs, (10) inflexibility, and (11) top-down approaches (Arslan 2007; Arslan & Cosgun 2008; Barakat, 2003; Chandler 2007; El-Anwar et al. 2009a; Hadafi & Fallahi 2010; Johnsonet al. 2006; Johnson 2007a).

In this sense, most significant research studies and guidelines acknowledge that THUs have discordant characteristics and have focused on solving the aforementioned issues. However, according to El-Anwar et al. (2009a) and Yi & Yang (2014), there are few studies that have considered THU optimization and sustainable construction such as: Johnson 2007a; El-Anwar et al. 2009a, b, c; El-Anwar, 2010,2013; Chen 2012; Karatas & El-Rayes 2014. Meanwhile, the use of THUs has been widespread in previous TH, as shown in Table 9.1.

Despite the weakness of the THU, the use of this TH model illustrates why decision-makers have chosen this model for DP. The factors in THU choice can be: (1) immediacy, (2) high demand, (3) DP pressure on the government, (4) lack of other options, and (5) avoiding the mass exodus of DP (Hadafi & Fallahi 2010; Quarantelli 1995). Therefore, for the aforementioned reasons, sometimes there are no suitable TH alternatives (e.g., apartment rental) besides THUs. Although this type of building, with its short life span, has generally been criticized in terms of sustainability, it is possible to determine a more adequate alternative within this category.

The **objective** of this study is to present a model for selecting the optimized THU by considering local characteristics and sustainability for regions using exclusively THUs, either because it is the only choice or because THUs are part of the region's TH program. The model is capable of identifying the optimized THU based on the satisfaction function of the involved stakeholders.

To that end, the Integrated Value Model for Sustainable Assessment (MIVES) from the Spain has been used in this study. The MIVES model, which is a multi-criteria decision-making method which incorporates the concept of a value function (Alarcon et al. 2011), assesses the main sustainability requirements of different alternatives which answer the same housing requirements. MIVES can also be calibrated to a certain time period and applied for different areas with varied local living standards and characteristics by adapting the indicators and weights defined in the requirements tree. MIVES has been used to evaluate sustainability and to make decisions in the fields of (1) university professors (Viñolas et al. 2009), (2) infrastructure (Ormazabal et al. 2008), (3) industrial buildings (Aguado et al. 2012; del Caño 2012; Fuente et al. 2015; Lombera & Rojo 2010; Pons & Aguado 2012; Pons & Fuente 2013), and (4) TH.

As a case study, four technologies suggested for THUs after the Bam earthquake are assessed. This chapter aims to reconsider these technologies to determine suitable options and to evaluate the sustainability of each technology. This study also assesses the THUs for a total usage period of 50 years: 5 years of temporary use and the rest as permanent use in the same location. This assumption has been made based on THUs of Bam, especially those which have been erected in private properties.

Table 9.1. The use of THUs in previous TH programs

Method / Natural disaster	Prefabricated		References
	Kit approach	Ready-made	
Mexico-1985	X		Johnson 2007b
Japan-1995	X	X	Johnson 2007b; UNISDR 2010
Turkey -1999	X	X	Arslan 2007; Arslan & Cosgun 2008; Johnson 2007a, b; Johnson et al. 2006
Iran-2003	X	X	Fayazi & Lizarralde 2013; HFIR 2013; Mahdi & Mahdi 2013; Rafieian & Asgary 2013
USA-2005	X	X	McIntosh et al. 2009; Sobel & Leeson 2006; UNISDR 2010
China-2008	X		UN 2009
New Zealand-2011	X	X	Giovinazzi et al. 2012; Siembieda, 2012
Turkey-2011	X	X	Erdik et al. 2012; IFRC, 2012
Japan-2011	X	X	EERI Special Earthquake Report 2011; Murao, 2015; Shiozaki et al. 2012
Iran-2012	X		HFIR 2012

9.2. Methodology

The decision-making process proposed in this study was organized in three choice phases: (1) initial, (2) middle, and (3) final choice, as shown in Fig. 9.1. In the *initial choice phase*, decision-makers consider the local potential based on TH features. In the *middle choice phase*, a requirements tree comprises criteria and indicators. The tree is designed with three varying levels (economic, environmental, and social) based on local characteristics (geographic and stakeholder requirements). In the *final choice phase*, a suitable decision-making model is used to determine sustainable THUs. Finally, the weights of the indexes have been determined by a group of experts using the Analytical Hierarchy Process (AHP) (Saaty 1990).

Certain indexes, such as material availability, plan, storey, and second life of THUs can have considerable effects on the design tree and weights. Meanwhile, in this research, only the second and third phases of the method have been applied in the case study to determine a suitable alternative, as shown in Fig. 9.1. Eight technologies had already been suggested by decision-makers as initial alternatives after the Bam earthquake, based on local potential.

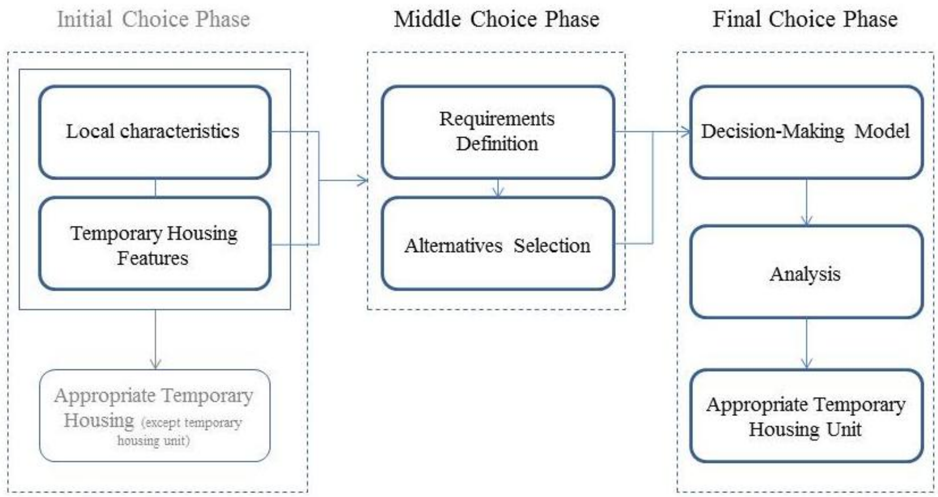

Fig. 9.1. Methodology for considering the TH process

9.3. Technologies Suggested for Constructing THUs in Bam

An earthquake that was estimated at Mw=6.6 by the USGS (United States Geological Survey) (Kuwata et al. 2005) occurred on September 26th, 2003, in Bam, which is located in southeastern Iran, approximately 1000 km southeast of Tehran (Anafpour 2008). The population of Bam was approximately 100,000 before the disaster (Ahmadizadeh & Shakib 2004). In the aftermath of the earthquake, 80% of buildings were completely destroyed (Havaii & Hosseini 2004), approximately 30% of Bam´s population was killed (Kuwata et al. 2005), and approximately 75,000 people were left homeless (Khazai &Hausler 2005).

In general, the Bam THU provision was based on two approaches: (1) THU provision in public camps and (2) THU provision on private properties. A total of 35,905 THUs were built: 26,900 units on private properties and 9,005 in 23 camps (Ghafory-Ashtiany & Hosseini 2008; Rafieian & Asgary 2013). THUs that were provided at camp sites had considerable problems. Khatam (2006) states the TH cost reached $60 million, while 10-20 percent of THUs have never been occupied.

In April 2004, most of the DP received THUs with an area of 18–20 m^2 (Fallahi 2007; Havaii & Hosseini 2004) that were built using different technologies by several contractors about seven months after the earthquake. The Foundation of Islamic Republic of Iran (HFIR) and the Minstry of Defence were selected for the responsibility of THU provision by the Iranian government. These organizations constructed THUs directly or by hiring contractors (Khazai & Hausler 2005).

Therefore, the HFIR delegated responsibility of THU design and construction to one of its subsets, called the Bonyadbeton Iran Co., and the experts at this organization designed eight alternatives based on four wall technologies and two roofing technologies, as shown in Table 9.2. Additionally, the designed THUs were considered in eighteen, twenty, and thirty-six square meter types with different plans and light steel structures. The eighteen and twenty m^2 plans are shown in Fig. 9.2.

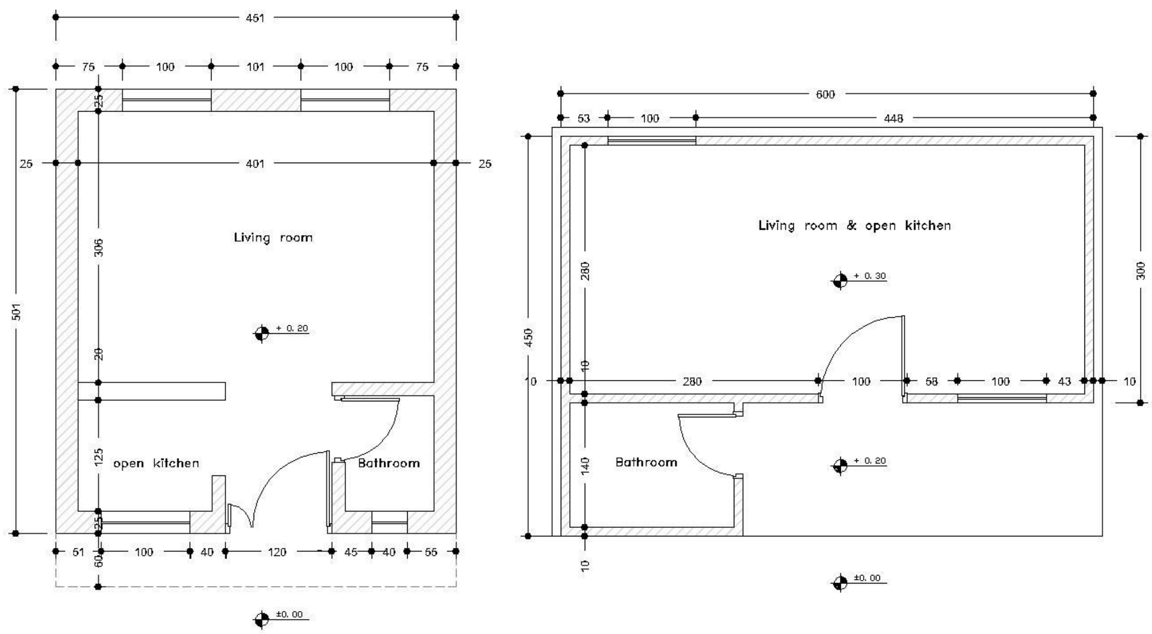

Fig. 9.2. Plan of a THU constructed in Bam after the 2003 earthquake; the left plan is the 20 m^2 type and the right plan is the 18 m^2 type

The wall technologies were: (1) *autoclaved aerated concrete blocks* (AAC Block), which is called "Siporex" in Iran; (2) cement block which is a concrete masonary unit (CMU); (3) *pressed reeds panel*, which is a prefabricated panel consisting of pressed reeds and joined by galvanized wire and framed by wooden or metal components, called "Cantex panel" in Iran. The two sides of a Cantex panel can be covered with different plasters, such as concrete and gypsum plaster (What Is Cantex? 2013); and (4) *3D sandwich panel*, which is a prefabricated lightweight structural panel consisting of a polystyrene core sandwiched between two welded steel wires meshes (Rezaifar et al. 2008), as shown in Fig. 9.3. Each side of the 3D panel is covered in sprayed concrete. Furtheremore, two materials were suggested for roofing: (1) *sandwich panel* roofing, which includes galvanized iron sheets on theoutside, polyurethane in the core, and foil cover for the inside, for a roof thickness two centimeters; and (2) *Corrugated galvanized iron* with four centimeters of polystyrene.

Table 9.2. Eight alternatives, including wall materials, roof materials, and construction cost per square meter.

Alternative	Abbreviation	Wall	Roof	Building Cost * (IRR./m^2) ***	Total cost ** (IRR./m^2)***
Alternative 1	AAC-S	Autoclaved aerated concrete blocks	Sandwich panels	516528	716528
Alternative 2	AAC-C	Autoclaved aerated concrete blocks	Corrugated galvanized iron	491194	691194
Alternative 3	CMU-S	Concrete masonry units	Sandwich panels	563750	763750
Alternative 4	CMU-C	Concrete masonry units	Corrugated galvanized iron	538417	738417
Alternative 5	PR-S	Pressed reeds	Sandwich panels	596972	796972
Alternative 6	PR-C	Pressed reeds	Corrugated galvanized iron	571639	771639
Alternative 7	3D-S	3D sandwich panels	Sandwich panels	719672	919672
Alternative 8	3D-C	3D sandwich panels	Corrugated galvanized iron	694339	894339

* Cost of construction materials, excluding lighting and piping

** Total of construction material cost including the coefficients: site preparation, area conditions, overhead, etc.; which had been considered by HFIR

*** At the time, one US$ equalled 8500 Iranian Rials (IRR.) (Havaii & Hosseini 2004)

9.4. Elements of the Sustainability Assessment Method Proposed for THUs

9.4.1. Requirements tree

The THU indexes have been defined based on Sustainability and Performance Assessment and Benchmarking of Buildings (Häkkinen et al. 2012) and collected TH data, including TH characteristics and TH stakeholders’ needs. The TH data have been collected through primary and secondary sources in previous TH programs, such as Iran, Turkey, USA, Japan, and especially the Bam recovery process in 2003. The general indexes involved in TH are organized into three main groups in Table 9.3, based on a global model according to (Anderson & UNHCR 1994; Berardi 2013; Davis & Lambert 2002; Johnson 2009; Karatas et al. 2010; McConnan 1998; UNHCR 1999; UNISDR 2010).

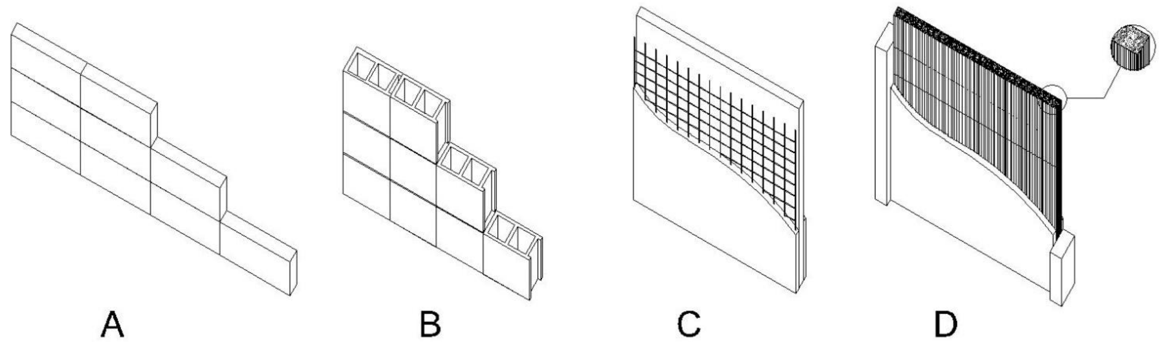

Fig. 9.3. View of the four wall technologies; (a) autoclaved aerated concrete block (AAC Block), (b) concrete masonry unit (CMU), (c), 3D sandwich panel wall and (d) pressed reeds panel

Therefore, as different locations have different standards and requirements (Davis 1978; Johnson 2007a), the indicators and weights can be different based on the local characteristics. Thus, based on the local characteristics and seminars results, the specific indicators for this case study have been collected from the general indexes of Table 3 and organized into three main requirements, as shown in Fig. 9.4.

The *economic requirement* (R_1) assesses the investment demanded of each proposed TH model over its entire life cycle. The *social requirement* (R_2) takes into account the impact of each TH alternative on DP as users of temporary houses and third parties who are involved. The *environmental requirement* (R_3) assesses the environmental effects of TH alternatives on the entire life cycle.

9.4.2. Economic indicators

I_1. The *building cost* indicator evaluates the construction cost of the building, including mobilization, site preparation, material, transportation, and installation for each unit.

I_2. The *maintenance cost* indicator considers the alternatives when these are used in the same location with the same function (THUs for the next natural disaster) or other function (permanent housing, low-income housing, etc.) based on this study scenario and technology possibilities. The service lifespans of TH materials have been assigned based on The Whitestone facility maintenance and repair cost reference 2012–2013 (Lufkin et al. 2012).

Table 9.3. The main influential indexes of TH by guideline

Requirement	Category	Definition
Economic	Construction	Considers the need for public expenditures to provide THUs.
	Maintenance/Reuse	Assesses the investment demanded during the operation phase.
Social	Health	Takes into account mental and physical aspects, such as risk resistance, sanitary conditions, community participation, infrastructure, etc.
	Convenience	Embraces indicators concern to comfortable conditions.
	Local capacity	Considers local characteristics, such as facilities, skilled labours, etc.
Environmental	Consumption	Considers resource consumption.
	Land use	Assesses land use change.
	Solid waste	Takes into account the amount of waste management during the construction and the demolition phases.

9.4.3. Social indicators

I_3. The *construction time* indicator assesses the alternatives in terms of normal time for the housing provision process, from the very raw materials up to delivery of the house.

I_4. The *risk resistance* indicator evaluates the strength of the alternatives against a natural or man-made disaster, such as a fire, earthquake, typhoon, tsunami, etc. Thus, this indicator has been assessed using two sub-indicators: S_1. *natural disaster risk* is evaluated by an assigned point system. As the steel structure of the case study alternatives was designed based on Iranian National Building Regulations, the steel frame generally has a low percentage of critical damping in an earthquake response (Dowrick 2009), and the ductility of the structure has not been considered. Therefore, the ductility of partition materials is assessed to determine the value of this sub-indicator. S_2. *Fire resistance* assesses the durability of the exterior wall material subject to fire, based on comparing minimum international fire resistance times as shown in Table 9.4.

I_5. The *comfort indicator* considers the rate of comfortable conditions in terms of indoor quality for THU users based on international code, as shown in Table 9.4. This indicator has two sub-indicators: S_3. *Acoustics range* considers the rate of air-borne soundproofing of each alternative by sound transmission class (STC). STC is calculated based on ASTM E413 and ISO/R717 (Long 2005). However, Long (2005) mentions the minmum STC rating of dwelling walls is 50 dB. In this study, the minimum STC rating has been set at 45 dB based on other standards, as shown in Table 9.4, and the high quality rating has been set at 65 dB according to Long. S_4. *thermal resistance* assesses the amount of heat and mass transfer from exterior walls (Feng 2004), which must resist passing the heat into and out of the building (Allen & Iano 2013). This sub-indicator controls the thermal comfort of alternatives, which is one of the main reasons to use spaces sheltered from the weather (Häkkinen et al. 2012).

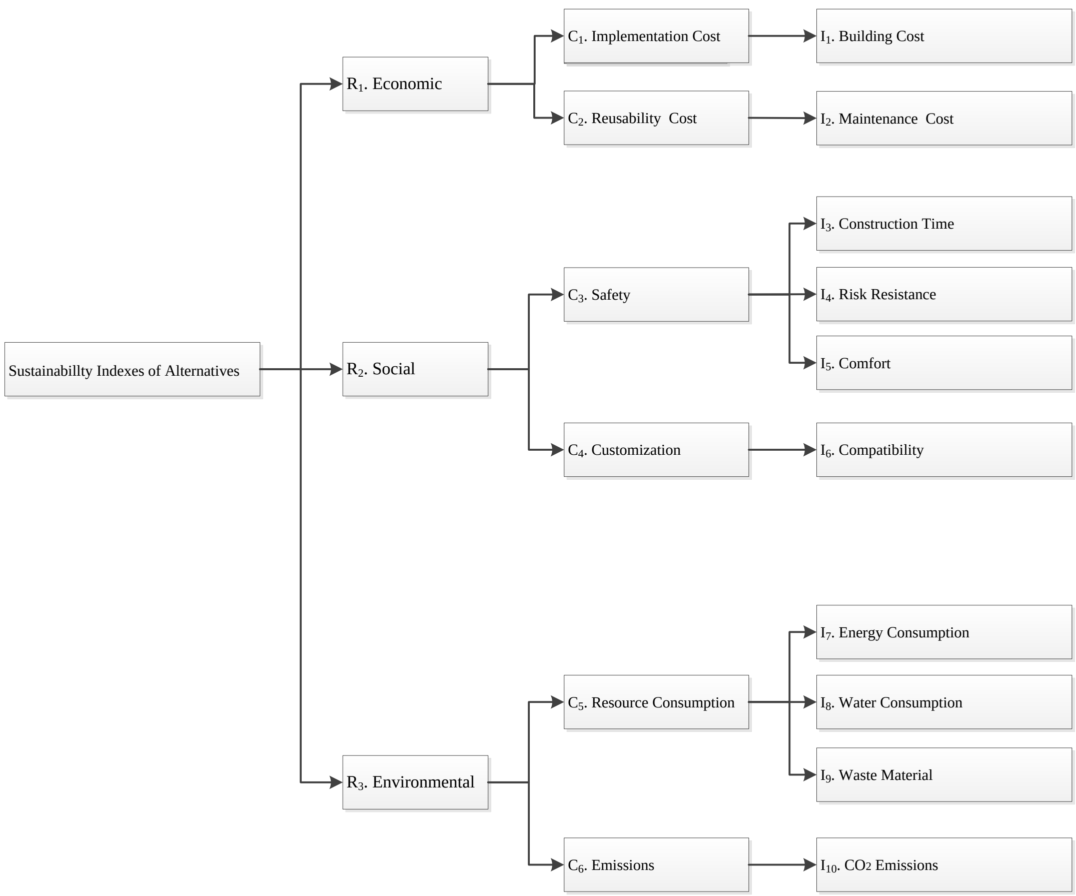

Fig. 9.4. Requirements tree designed for this model

I_6. The *compatibility* indicator evaluates the adaptability of THU characteristics to the local culture. This indicator includes three sub-indicators: S_5. *cultural acceptance,* which considers whether technologies are consistent with DP culture, indigenous material, and pre-disaster local housing, and can be a reason for THU rejection (Marcillia & Ohno 2012; UNDRO 1982). Therefore, the alternatives are evaluated based on similarity of the technologies to common pre-disaster local housing by an assigned point system. S_6. *skilled labour* index considers the adaptability of technologies with local labour proficiency. THU technologies that are provided by highly skilled labour require training, professional equipment, etc.

Table 9.4. Exterior wall standards for residential buildings

			Exterior wall standards	References
Acoustic range	Iran		Bedroom: R'_w >45; Living room: R'_w >40; Kitchen: R'_w >35	INBC part 18 2009
	USA		Grade 1:STC>55; Grade 2:STC>52; Grade 3:STC>48 (general STC>50)	Garg et al. 2011
	UK		$D_{nT,w} + C_{tr}$ >45	Building Regulations 2010
	Germany [a]		Class A: R'_w >68; Class B: R'_w >63; Class C: R'_w >57	Garg, Sharma, & Maji 2011
Fire resistance (h)	Iran		1	Publication No.613 2013
	USA		1	IBC 2009
Thermal Resistance	Iran [b]	Light	Group 1: R>2.8; Group 2: R>2.1; Group 3: R>1.5	INBC part 19 2011
		Heavy	Group 1: R>1.9; Group 2: R>1.4; Group 3: R>1.0	
	UK		U-value: 0.3–0.4	Papadopoulos 2005

[a] Row housing

[b] Light wall: surface mass < 150 kg/m^2 - Heavy wall: surface mass > 150 kg/m^2

R'_w : Weighted sound reduction index (dB); $D_{nT,w} + C_{tr}$: Airborne sound insulation (dB); R: Thermal resistance (m^2.K/W)

Consequently, these technologies cause some problems, such as: (a) insufficient THU quality, (b) minimum DP participation, (c) low level of maintenance, (d) unemployed local labour, (e) migration of non-local labour to affected areas and vice versa, (f) construction delays, and (g) an increase in required expenditures (Abulnour 2014; Kennedy et Al. 2008; Ophiyandri et al. 2013; Coffey, & Trigunarsyah 2012; Transitional Shelter guidelines 2012). Therefore, a technology that requires a minimum skill level is the more sufficient technology (Wallbaum et al. 2012). S_7. *Flexibility* evaluates the modifiability of each technology by users during the construction process and usage phase. THUs are usually provided based on a top-down approach, with minimum stakeholder participation as a weakness of the process (Davidson et al. 2008). Therefore, TH projects can be failures because of THU abandonment (Davidson et al. 2007) or lack of resident responsibility during the maintenance phase (Arslan & Unlu 2006). In other to objectively measure I_6 and its sub-indicators, point systems have been used.

9.4.4. Environmental indicators

Buildings cause resource consumption and gas emissions during their lifespans, including the construction, usage, and demolitions phases (Dakwale et al. 2011; Miller et al. 2015; Nkwetta & Haghighat 2014; Pons & Wadel 2011). Thus, four indicators should be designed to assess the TH impact on the environment based on Life-Cycle Assessment (LCA), as stated in ISO 14040. The life-cycle assessment of the building industry can be arranged in four phases: (1) manufacturing (building material production, transportation); (2) construction (activities, transportation, and water consumption); (3) use (water and energy consumption, such as electricity or gas); and (4) demolition (Bribia et al. 2009; Mosteiro-Romero et al. 2014; Pacheco-Torres et al. 2014).

I_7. The *energy consumption* indicator evaluates the amount of energy consumed based on LCA in three of the four phases: manufacturing, construction, and demolition. Inventory of Carbon & Energy (ICE) (Hammond & Jones, 2011) has been used to evaluate energy consumption.

Energy consumed to provide comfortable conditions during the operations phase has not been evaluated in the energy consumption indicator. The thermal resistance sub-indicator embraces both comfortable conditions and energy consumption. Based on the MIVES concept, indicators should be independent from each other and considered once; thus, this indicator has not been assessed again. Additionally, as alternatives conditions were almost same during the operation phase in terms of other environmental indicators, these indicators have not considered for this phase.

I_8. The *water consumption* indicator assesses the amount of water usage in the three mentioned phases. The amount of water consumption has been determined based on Wuppertal institute for climate, environment and energy (2011).

I_9. The *waste material* indicators evaluate the amount of waste material remaining from the manufacturing, construction, and demolition phases. This research considers the waste material range of each technology during the construction phase.

I_{10}. The *CO_2 emissions* indicator measures the amount of CO_2 emissions for each alternative in the three aforementioned phases, according to a Life-Cycle Assessment (LCA). To evaluate CO_2 emissions, Inventory of Carbon & Energy (ICE) (Hammond & Jones 2011) has been used because this database raises the possibility of considering used materials individually.

Table 9.5. Common materials for all alternatives

Component	Material
Foundation	Strap footing foundation, the height is 0. 35 m
Floor	lean concrete 150 kg/m^3, the thickness is 0.15 m and Iranian mosaic tile
Structure	Steel hollow square section
Footing (Plinth)	Brick or block, the height is 0.20 m
Window	Metal widow, the dimension is 1.00 m *1.00 m
Door	Metal door, the dimension is 2.00 m *1.00 m
Mortar	Cement mortar 1:6

9.5. Analysis

This study aims to reassess the four alternatives shown in Fig. 9.3 to determine the most sustainable alternative and to evaluate the sustainablity of technologies using a newly designed sustainability model based on MIVES, with a simplified Life-Cycle Assessment (LCA), local standards, and local needs, by considering all indexes and the entire life cycle of THUs. In this resaerch, four alternatives with corrogated galvanized iron roofing (AAC-C, CMU-C, PR-C, and 3D-C) have been assessed. The two roof materials and costs are almost equal.

To evaluate the sustainability values of different technologies in this case study based on defined indexes, one square meter of these building designs is considered. The common materials have not considered by this model. The same construction materials for all alternatives excluding service, kitchen, electrical, and mechanical materials are summarized in Table 9.5. Furthermore, the technologies' materials and their characteristics are individually organized in Table 9.6 and as assembled in Table 9.7.

Table 9.6. Major materials and their properties

Features / Material	Density (kg/m^3)	Thermal conductivity (w/(m.k))	Embodied energy (MJ/kg)	Embodied CO_2 ($kgCO^2/kg$)	Water consumption (kg/kg)	References
Cement mortar (1:6)	1650	0.72	0.85	0.136	-	Hammond & Jones 2011
Cement mortar (1:3)	1900	0.93	1.33	0.221	-	Hammond & Jones 2011
Steel	7800	45	13.1	0.72	63.67	Hammond & Jones 2011; Wuppertal institute 2011
concrete 16/20 MPa [a]	2350	2.2	0.70	0.100	3.42 [a]	Hammond & Jones 2011; Wuppertal institute 2011
Autoclaved aerated concrete block	500	0.16	3.50	0.24 to 0.37	13.42 [a]	Hammond & Jones 2011; Wuppertal institute 2011
Concrete masonry block	2050	0.9	0.59	0.063	11.49 [b]	Hammond & Jones 2011; Wuppertal institute 2011
Reed	120-225 76 75.6	0.055-0.090 0.076 0.08-0.09	- [c]	- [c]	- [c]	Hammond & Jones 2011; Miljan et al. 2014; Pfundstein et al. 2012; Vejeliene et al. 2011
Polystyrene (E.P.S.)	15	-	88.6	3.29	137.68	Hammond & Jones 2011; Wuppertal institute 2011

[a] General

[b] Cellular concrete 600 kg/m^3

[c] Generic wood (As the embodied energy and CO_2 are not available in Inventory of Carbon & Energy (ICE), 2011, the parameters of generic wood have been used)

In this stage, the parameters necessary for evaluating each indicator are assigned. According to Alarcon et al. (2011), in the next step, the tendency of the value function (increase or decrease) is determined, and then the points that produce minimum and maximum satisfaction (S_{min} and S_{max}) are assigned. Finally, the shape of the value function (concave, convex, linear, S-shaped) and the mathematical expression of the value function are determined.

According to Alarcon et al. (2011), when satisfaction increases rapidly or decreases slightly, a *concave-shaped* function is the most suitable. The *convex* function is used when the satisfaction tendency is contrary to the concave curve case. If satisfaction increases/decreases steadily, a *linear* function is presented. An *S-shaped* function is used when the satisfaction tendency contains a combination of concave and convex functions.

The parameters, tendency and shape of the value function for each indicator are determined from international guidelines, scientific literature, Iranian National Building Regulations, and the background of experts, including professors and HFIR engineers and experts that participated in the seminars, as shown in Table 9.8. In the next step, the value function is obtained based upon the general exponential in MIVES.

The indicators tendencies have been determined based on seminars results and cases study data, for instance to evaluate the sustainability value of the building cost indicator (I_1), X_{min} = 600,000 IRR /m^2; this price had been suggested by the HFIR and accepted by the local government as a base price for each square meter of THUs. X_{max} = 1,350,000 IRR/m^2 based on the cost of other THU types (Khazai & Hausler 2005). Additionally, satisfaction decreases rapidly when the building cost increases, a decreasing, convex (DCx) curve is assigned for the tendency of this indicator value function, as shown in Fig. 9.5.

Regarding the shape of the value functions assigned to the indicators, six decrease in a convex manner (DCx) and four increase, of which two are S-shape (IS) and two increase in a convex manner (ICx). Furthermore, the X_{min} and X_{max} of each indicator are defined, as shown in table 9.8.

Table 9.7. The important features of the technologies

Technology (wall)	Components characteristics			Thermal resistance $(m^2.k)/w$	Fire resistance (h)	STC	Ductility	Construction time	References
		Material	Dimension (cm)						
Autoclaved aerated concrete blocks		AAC	60*10*25	0.625[a]	4	35[a]	Medium to low [b]	Low	Charleson 2008; DuPree 1980; Hammond & Jones 2011; Ingberg, Mitchell, & NIST 1944; International Masonry Institute 2010
	in	Gypsum plaster	3						
	out	Cement plaster	2.5						
Concrete masonry units		CMU	40*20*30	0.222[a]	1.75	43-48 [a]	Medium to low [b]	Very low	Cavanaugh & Wilkes 1999; Charleson 2008; HFIR 2013; Ingberg et al. 1944;
	in	Gypsum plaster	3						
	out	Cement plaster	2.5						
Pressed reeds		Reeds panel	5	0.667[a]	0.5	$R_{w}=15$ [c]	Medium to low [b]	Medium	Charleson 2008; Díaz, Jiménez et al. 2012; IS 4407-1967 2002; HFIR 2013
	in	Gypsum plaster	3						
	out	Cement plaster	2.5						
3D panels		EPS	5	R11 1.9373 [d]	1.5 [d]	40 [d]	Medium to high [a]	high	Charleson 2008; HFIR 2013; Publication No. 385; Poluraju & Rao 2014; Sarcia 2004
		Steel mesh	0.25/0.25/ 8/8						
	in	Sprayed concrete	3						
	out	Sprayed concrete	3						

[a] Without plaster

[b] General

[c] Weighted sound reduction index of 5 cm reeds without plaster / 1.8 cm MDF on each side and 5 cm reeds in the core R_w=39

[d] 1.5-inch layer of concrete on either side and 2.5-inch EPS in the core (1Btu/h.ft^2.°F = 5.678 W/m^2.K), and the sprayed concrete is 120 pounds per cubic foot .

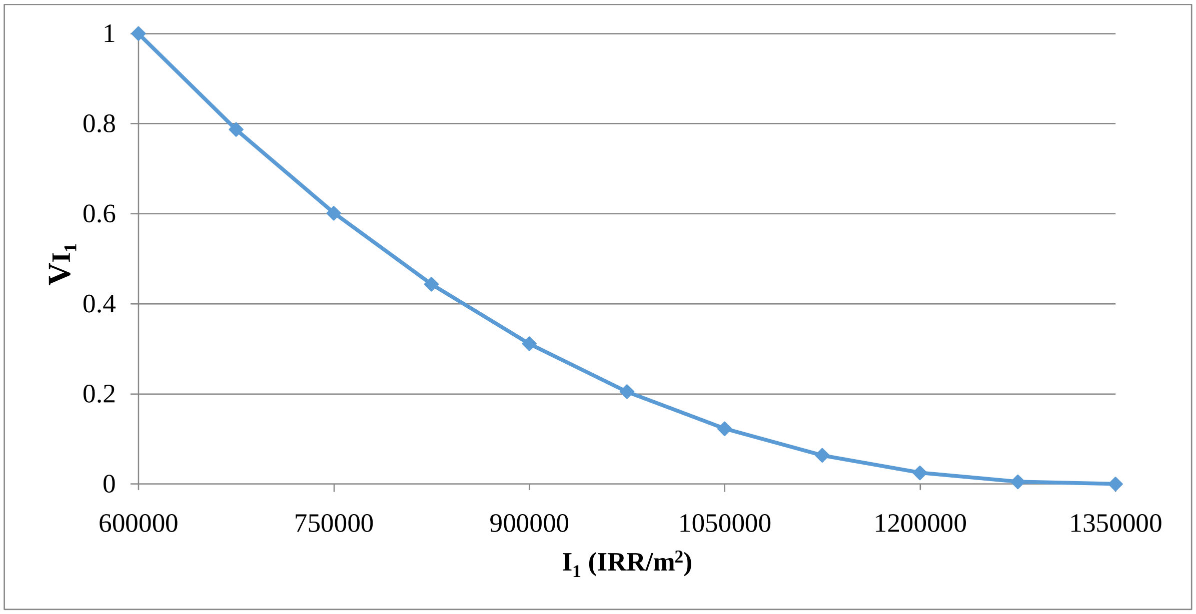

Fig. 9.5. Value function of building cost indicator (I_1)

Table 9.8. Parameters and coefficients for each indicator value function.

I	Unit	X_{max}	X_{min}	C	K	P	Shape	References
I_1	currency/m^2	$13.5 \cdot 10^4$	$0.6 \cdot 10^6$	$1.4 \cdot 10^6$	0.1	2.3	DCx	HFIR 2013; Khazai & Hausler 2005
I_2	currency/m^2	$5.6 \cdot 10^3$	$2.3 \cdot 10^3$	$0.8 \cdot 10^4$	0.01	1.5	DCx	HFIR 2013; Iranian Publication No. 385; Lufkin, et al. 2012
I_3	pts.	1	0.00	1.5	0.8	2.5	ICx	HFIR 2013; Pons & Aguado 2012
I_4	pts.	1	0.00	0.25	0.2	2	IS	HFIR 2013
I_5	pts.	1	0.00	0.5	0.8	2	IS	HFIR 2013
I_6	pts.	1	0.00	0.35	0.1	1.8	ICx	HFIR 2013
I_7	MJ	$2.5 \cdot 10^2$	$1.2 \cdot 10^2$	$0.2 \cdot 10^3$	0.8	1.6	DCx	Hammond & Jones 2011; HFIR 2013
I_8	kg	$2.15 \cdot 10^3$	$2.4 \cdot 10^2$	$2.1 \cdot 10^3$	0.2	1.6	DCx	HFIR 2013; Wuppertal institute 2011
I_9	%	20	5	30	0.6	2	DCx	Harris 1999; HFIR 2013; Iranian Publication No. 385; Saghafi & Teshnizi 2011
I_{10}	kg CO_2	26	13	25	0.3	1.4	DCx	HFIR 2013; Hammond & Jones 2011

Xmax: maximum value indicator; Xmin: minimum value indicator; C: establishes, in curves with $P_i > 1$, abscissa's value for the inflexion point; K: defines the response value to C; P: is a shape factor

Additionally, some indicators comprise sub-indicators, such as I_4, I_5, and I_6. The defined process for indicators is applied to sub-indicators as well, so the demanded parameters and shape of the value function are assigned to each of the sub-indicators as shown in Table 9.9. The sub-indicator functions also have the following shapes: seven increase, of which four are S-shape (IS) and three increase in a convex manner (ICx).

Table 9.9. Parameters and coefficients for each sub-indicator value function.

	Sub-indicator	Unit	X_{max}	X_{min}	C	K	P	Shape	References
I_4	Natural Disaster Risk	pts.	1	0.00	0.55	0.8	2.5	IS	Charleson 2008
	Fire Resistance	h(s)	4	0.00	2	0.8	3.5	IS	Cavanaugh & Wilkes 1999; IBC 2009; IS 4407-1967
I_5	Acoustic	STC	60	30	6	0.2	2	IS	Building Regulations 2010; Garg et al. 2011; INBC part 18 2009; Long 2005
	Thermal Resistance	m^2.k/w	2.5	0.00	1.6	0.8	2.5	IS	Hammond & Jones 2011; INBC part 19; Sarcia 2004
I_6	Cultural Acceptance	pts.	1	0.00	1	0.8	2	ICx	HFIR 2013; UNDRO 1982
	Skilled Labour	pts.	1	0.00	2	0.1	2	ICx	Corsellis & Vitale 2005; HFIR 2013; UNDRO 1982
	Flexibility	pts.	1	0.00	1.5	0.8	1.5	ICx	HFIR 2013; UNDRO 1982

After the assessment of the sustainability value of the indicators for each alternative technology, the formula that is presented in Eq. (9.1) should be applied to each tree level. In this equation, the indicator value ($V_i(x_i)$) has previously been determined and the weights (λ_i) are assigned to determine the sustainability value of each branch. For the multi-criteria case, the additive formula corresponding to Eq. (9.1) is applied to determine the sustainability value of each technology.

$$V = \sum \lambda_i \cdot V_i\,(x_i) \qquad (8.1)$$

$V_i\,(x_i)$: The value function of each indicator and each criterion

λ_i : The weight of considered indicator or criterion.

Therefore, based on previous studies and the knowledge of the professors and HFIR experts involved in the seminars, the weights for requirements, criteria, and indicators were assigned using the Analytical Hierarchy Process (AHP), as shown in Table 9.10. Finally, Eq. (9.1) is applied for each level of the tree when the value function of each index (V_{x_k}) and its weight (λ_k) had been determined.

Table 9.10. Requirements tree with assigned weights.

Requirements	Criteria	Indicators	Sub-indicators
R_1. Economic (**45**%)	C_1. Implementation Cost (85%)	I_1. Building Cost (100%)	
	C_2. Maintenance Cost (15%)	I_2. Reusability Cost (100%)	
R_2. Social (**25**%)	C_3. Safety (60%)	I_3. Construction Time (36%)	
		I_4. Risk Resistance (42%)	S_1. Natural Disaster Risk (50%) S_2. Fire Resistance (50%)
		I_5. Comfort (22%)	S_3. Acoustic (50%) S_4. Thermal Resistance (50%)
	C_4. Customization (40%)	I_6. Compatibility (100%)	S_5. Cultural Acceptance (45%) S_6. Skilled Labour (30%) S_7. Flexibility (25%)
R_3. Environmental (**30**%)	C_5. Resources Consumption (67%)	I_7. Energy Consumption (47%)	
		I_8. Water Consumption (18%)	
		I_9. Waste Material (35%)	
	C_6. Emissions (33%)	I_{10}. CO_2 Emissions (100%)	

9.6. Results and Discussion

The results from this evaluation are a sustainability index (I), requirements values (V_{Rk}), criteria values (V_{Ck}), and indicators values (V_{Ik}) for each alternative shown in Table 9.11. This sustainability index (I) quantifies the four technologies from more to less sustainable: CMU, PR, AAC and 3D, with indexes of 0.53, 0.53, 0.50 and 0.36, respectively. The results show that the case study alternatives mostly fell in the middle of the sustainability index range. As permanent housing standards have been used to evaluate indicator values, especially in terms of social aspects, the range of the obtained sustainability indexes is not large. However, if the quality of THUs is equal to permanent housing, it is very difficult to motivate DP to move to their new permanent housing. Thus, the difference between temporary and permanent usage should be considered.

Table 9.11. Sustainability index (I), requirements (V_{Rk}), criteria (V_{Ck}), and indicator (V_{Ik}) values for the four alternatives

	I	V_{R1}	V_{R2}	V_{R3}	V_{C1}	V_{C2}	V_{C3}	V_{C4}	V_{C5}	V_{C6}
AAC	0.50	0.76	0.39	0.20	0.74	0.87	0.43	0.34	0.25	0.11
CMU	0.53	0.62	0.39	0.49	0.63	0.59	0.29	0.55	0.48	0.51
PR	0.53	0.55	0.19	0.79	0.55	0.52	0.21	0.15	0.74	0.9
3D	0.36	0.28	0.38	0.46	0.32	0.06	0.61	0.02	0.43	0.52

	V_{I1}	V_{I2}	V_{I3}	V_{I4}	V_{I5}	V_{I6}	V_{I7}	V_{I8}	V_{I9}	V_{I10}
AAC	0.74	0.87	0.2	0.83	0.04	0.34	0.1	0.55	0.3	0.11
CMU	0.63	0.59	0.11	0.41	0.36	0.55	0.79	0.03	0.3	0.51
PR	0.55	0.52	0.37	0.18	0.01	0.15	0.87	0.98	0.44	0.9
3D	0.32	0.06	0.52	0.65	0.7	0.02	0.33	0.66	0.44	0.52

	V_{S1}	V_{S2}	V_{S3}	V_{S4}	V_{S5}	V_{S6}	V_{S7}
AAC	0.40	1.00	0.13	0.08	0.66	0.49	0.15
CMU	0.40	0.39	0.72	0.01	1.00	0.57	0.15
PR	0.48	0.01	0.00	0.09	0.33	0.36	0.15
3D	0.85	0.25	0.43	0.75	0.09	0.06	0.15

The specific sustainability indexes and requirement values of the four technologies are shown in Fig. 9.6. This consideration shows that each technology has strengths and weaknesses, while the CMU and PR technologies obtained higher sustainability index values. In general, the AAC and CMU technologies achieved the highest social requirement value (0.39); meanwhile, the AAC and PR technologies obtained the highest economic requirement (0.76) and environmental requirement (0.79), respectively.

In terms of the economic requirement, the AAC technology has obtained the highest value among the alternatives, as the construction cost of this technology was the lowest according to the HFIR at that time, as shown in Fig. 9.6. The economic values of THUs are closely related to the economic power of the affected area.

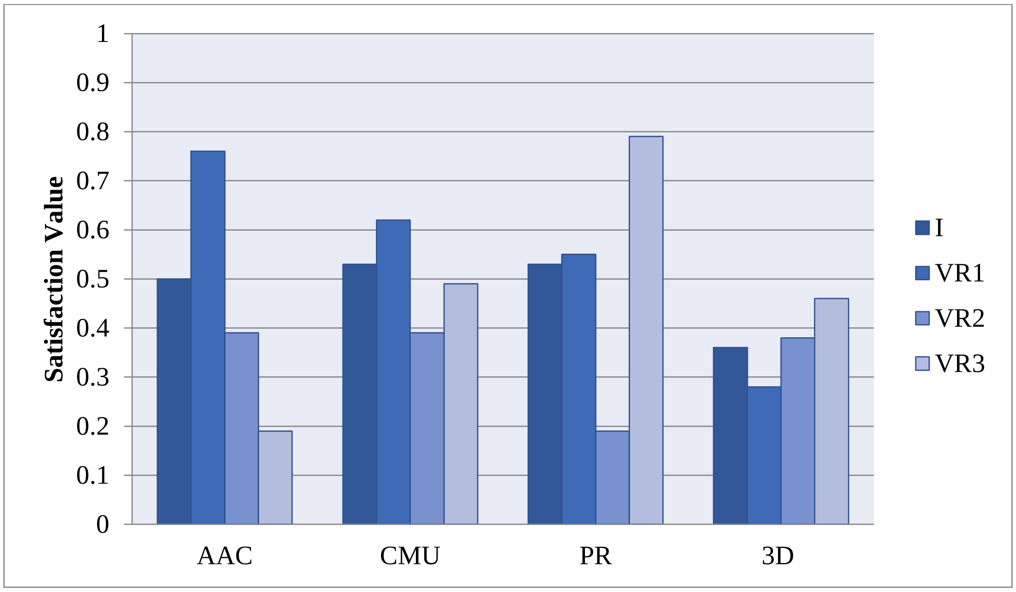

Fig. 9.6. Requirements values for the four alternatives

In terms of social requirements, ACC, CMU, and 3D technologies are almost the same, while the PR technology obtained the lowest social requirement value. The model results show that the alternatives must be enhanced for long-term use in terms of social aspects; however, these alternatives are generally acceptable for use in emergencies as a THU, except for PR. Because of the low fire resistance rating of PR technology, this technology must be enhanced with a longer fire resistance time to be reconsidered.

The AAC and CMU technologies have minimum construction time indicator values, and these technologies obtained maximum customization criterion values, especially for CMU. These two technologies also have maximum fire rating.

3D has a maximum construction time indicator and natural disaster resistance sub-indicator. Moreover, this technology is acceptable in terms of fire rating, thermal resistance, and STC rating; however, this technology obtains a low social requirement satisfaction value compared to AAC and CMU. Because 3D technology was unfamiliar for the DP of Bam, this technology was refused and could not achieve a high social value. Meanwhile, AAC and CMU have high compatibility indicator values, and PR has a lower value.

In terms of environmental requirements, the values of the four technologies are, from greatest to least, PR, CMU, 3D and AAC; with indexes 0.79, 0.49, 0.46 and 0.19, respectively. PR has the highest environmental requirement value; this technology obtained the highest values of any alternative in all indicators related to the environment, as shown in Fig. 9.7. In this case, PR has the highest energy consumption value, and AAC has the lowest. The energy consumption values of CMU and 3D technologies are located between those of PR and AAC, from high to low, respectively.

CMU consumes more water than other technologies, although the amount of water consumed is negligible compared to the operation phase; thus, a low weight of 18% has been assigned for the *water consumption* indicator.

CMU and AAC have lower values for waste material than the other technologies because CMU and AAC are masonry technologies. According to Table 9.11, the waste material values of the alternatives are lower than the middle value range, 0.50. Furthermore, CO_2 emissions values for the four technologies are ranked, from most to least, PR, 3D, CMU, and AAC, with indexes of 0.9, 0.52, 0.51 and 0.11, respectively.

In the end, the most sustainable technology(s) has been determined using economic, social, and environment requirement weights of 45%, 25%, and 30%, respectively, as determined by experts. Consequently, CMU and PR technologies obtained the highest sustainability index and AAC comes after the first two technologies. Beyond a determination of the sustainability indexes of alternatives, this study has presented a model that has the ability to specify strengths and weaknesses of alternatives. Meanwhile, this decision-making model is capable of considering alternatives in various scenarios using different requirement weights to obviate deficiencies and increase the acceptability range of THUs.

Therefore, each technology has been considered with different requirement weights to obtain suitable alternatives in diverse conditions and situations, with the suitable requirement weights assigned by experts. Sixteen different scenarios have been considered to determine sustainability index trends of the four technologies when the requirement ratios would be different, as shown in Fig. 9.8. The highlighted point on the horizontal axis (economic 45%, social 25%, and environmental 30%) shows the sustainability indexes of technologies based on suitable weights chosen by experts.

If the environmental weight increases compared to the social weight, such as the first point on the horizontal axis in Fig. 9.8 (economic 47%, social 18%, and environmental 35%), PR becomes a more sustainable technology. If the social requirement weight increases, CMU and AAC will be suitable alternatives, although the social and environmental requirement weights can qualify either CMU or ACC as a final result. Therefore, if the quality life of DP were the first priority for decision-makers, these two technologies could be suitable alternatives. However, CMU obtains a high sustainability value in this condition, several times more than that of ACC and the other technologies.

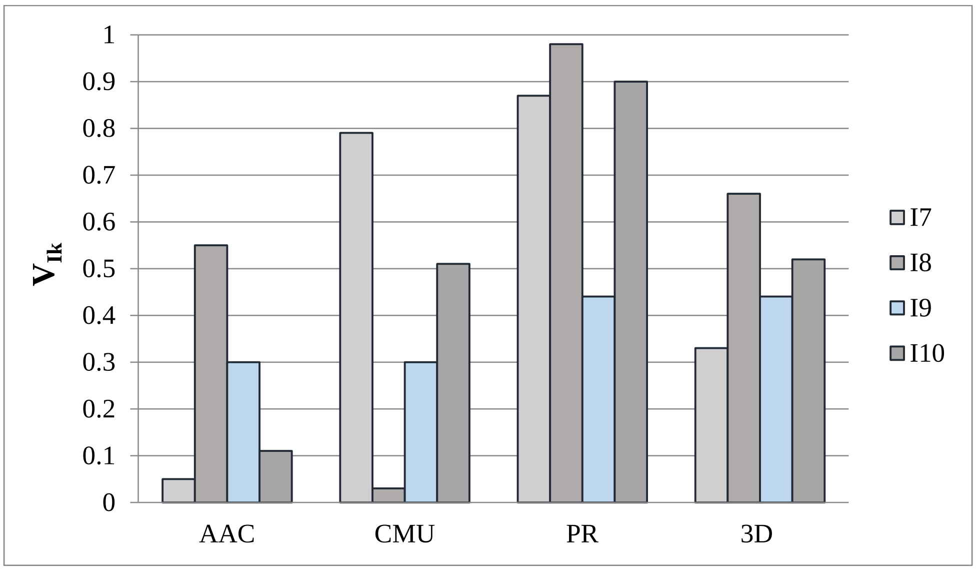

Fig. 9.7. Environmental indicator values for the four alternatives

The sustainability indexes for 3D technology did not change drastically when considering different requirement weights. As this technology was more expensive, unfamiliar to DP, and consumed high energy compared to CMU and PR, 3D cannot obtain a high sustainability index. Additionally, the trend of the 3D sustainability index will approach other technology points if the economic requirement weight decreases drastically.

In the end, it should be mentioned that, according to the results of this study, CMU obtained the highest sustainability index. However, this technology has been an unsuitable alternative for THUs at first glance because of its weaknesses, such as construction delivery time. To choose a suitable THU, all factors, including essential and lower-priority factors, must be considered.

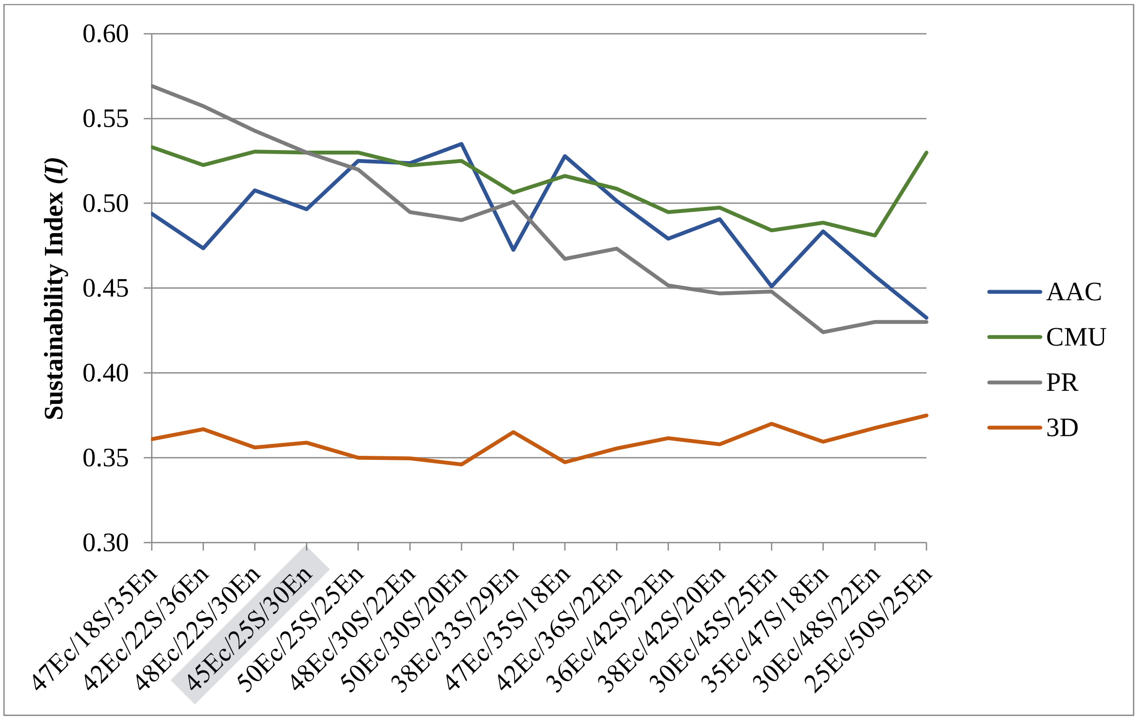

Fig. 9.8. Sustainability indexes of the four technologies with different requirement weights (economic (Ec), social (S), and environmental (En))

9.7. Conclusions

This chapter presented a new sustainability assessment model that has been specifically configured to analyse THU alternatives. This model enables decision-makers to determine more sustainable THUs after the initial choice phase is complete and acceptable or available alternatives have been chosen. This model is based on the MIVES methodology, which has proven to be a suitable strategy for conducting multi-criteria decision processes for an integral sustainability analysis of each alternative. This methodology can be used for different locations with diverse characteristics without being limited by the present conjuncture. Therefore, this model is an ideal tool for choosing THUs, because it embraces the essential aspects of THU provision, such as quick and easy localization, the ability to address THU issues consisting of various criteria with different priorities, and using a value function system that is a suitable approach to the particularities of THU indicators.

For the application example, a total of four different THUs from the Bam earthquake in 2003 have been assessed to test the designed model and analyse the THUs used. In this sense, CMU and PR have the highest sustainability indexes, though CMU has a greater impact on the environment than does PR. Nevertheless, CMU technology has been chosen as the more sustainable of the technologies, because this technology obtained higher sustainability indexes with regard to different requirement weights, as shown in Fig. 9.8. Additionally, the local alternative can be an appropriate solution based on the results of this study; however, decision-makers can improve the sustainability index of this alternative by recognizing low indicator values and modifying them.

However, this model has only been applied to determine qualities of the four THU alternatives used in Bam. This model can be used to determine the most sustainable alternative for any type of post-disaster TH. To this end, some indicators and weights should be adjusted to the new location's characteristics and requirements. Furthermore, this study provides this customizable model as a specific approach to dealing with TH for future research.

Chapter 10

Conclusions

10.1. Introduction

Temporary housing (TH) management is a matter of paramount importance due to the population growth, especially in areas prone to natural disasters, as well as the change of natural hazards characteristics. These accommodations, especially THUs, are criticized in terms of sustainability concepts (economic, social, and environmental aspects). In this regard, new case studies that deal with particular problems, characteristics, limitations, potential solutions and categorization of the most relevant factors have been analysed in deep by using two new models proposed in this research; this models being based on a novel multi – criteria decision – making (MCDM) model named MIVES. These models have resulted to be capable of minimizing negative impacts and facilitating the decision-making process. The main and specific conclusions to answer to the established objectives are presented and discussed in this conclusions chapter. In addition, several uncovered topics are proposed in the second part of this chapter as future research lines.

10.2. Main conclusions

The critical analysis of the results obtained from the application of both models proposed permit to establish the following conclusions with respect to the sustainability of TH in urban areas:

- A **new conceptual model oriented to select the sustainability of post-disaster TH alternatives** based on steps scenarios has been proposed. This has been designed and validated by the two case studies: site location strategy of the Bam recovery program and used TH aftermath of earthquake and tsunami in Aceh, 2004. This model assists decision-makers for choosing the most suitable strategy, which brings higher beneficiaries' satisfactions.
- A **new model to support decision-makers in choosing site locations for post-disaster temporary housing units (THUs)** among available alternatives in urban areas has also been proposed. The model has been meant to deal with the selection of site location based on coupling MIVES and Knapsack algorithm. This combined model has high applicability in those cases for which there exit several combinations of potential sites with different associated sustainability.
- A **new model to assess the sustainability of post-disaster THUs** has been presented and validated by comparing results of a real study cases, the THUs of the Bam recovery program. The representativeness of the results obtained with the model lead to confirm that this is a suitable method to assist decision-makers. The use of the proposed approach allows maximizing the stakeholders' satisfaction since local conditions can be objectively considered by using MIVES.

10.3. Specific conclusions

This study has been conducted following descriptive and *operational* approaches. The *descriptive* approach embraces the problems, requirements, limitations, potential responses, strategies and their outcomes while the *operational* is dealt with models that permits to assess the sustainability in different fields of the TH. The combination of both approaches allowed overcoming the problems and present new strategies for assessing the sustainability of post-disaster TH in urban areas.

In this regard, the specific conclusions derived from the **descriptive** approach are:

- The vast majority of the studied cases struggled with TH without considering the level of prosperity and local potentials.
- A direct relationship between stakeholder's satisfaction and the local initial conditions (e.g., prosperity and welfare of the affected area, pre-disaster housing) is difficult to be established.
- The three main vertexes of TH are the natural hazards' properties, local characteristics, and TH properties. However, the impacts of these elements on the recovery program outcomes differ from one case to another; even, same aspects can lead to antithetical effects depending on the case.
- Negative impacts of THUs can be reduced when these units are used as whole or part of permanent housing. Additionally, besides the considerable impacts of THUs, site location of all post-disaster accommodation types in general has substantial impacts on economic, social, and environmental aspects.
- All type of TH could be sustainable, provided all factors of problem are considered from very beginning stages of planning phase until end life of alternatives based on local characteristics including material and immaterial aspects.
- Some parts of TH sustainability issue, have been formed based on some myths and prejudices that need to be assessed with pinpoint accuracy in order to realize truths, as some studies have done. However, these prejudice beliefs certainly emanated from some facts; these could be inapplicable for other cases.
- In order to achieve suitable results is extremely required to distinguish between the urban and rural areas.
- The Integrated Value Model for Sustainable Assessment (MIVES) has been confirmed to be a suitable method to assess objectively the sustainability of TH.

- Each factor involved in a TH program could be relevant and, thus, each is necessary to be considered. In this regard, negligible indicators for a specific case can have great effects on the others. Furthermore, some factors of post-disaster accommodation can completely be in conflict, such as proximity to pre-disaster private properties and protecting displaced population form future hazards.

In general, to deal with TH is required to address a platform capable to include all those aspects involved, without imposing a specific strategy. By means of this, decision-makers, who have been informed of environmental issues, possibilities, limitations and the outcomes of various approaches, are assisted for choosing the most suitable strategy for a specific case. In other words, customizable tools (able to consider local particular conditions) should be provided to emergency managers so that this can define different TH strategies.

Besides, within the **operation** approach of this research, the results and analyses derived from the multi-criteria models developed have led to the following conclusions:

- Each TH alternative should be considered within the sustainability assessment procedure; even, those TH strategies that could lead to substantial negative impacts for the stakeholders. **(Chapter 4 and 9)**
- Sites located in different districts have the best social index value. Indeed, these sites can give higher satisfaction to displaced population, involving labour and neighbours. However, these sites have lower economic and environmental index values. Moreover, these disperse sets imply an incensement of transportation needs and these are usually located at greater distances from resources. Consequently, these cause increases in expenses and environmental impacts. **(Chapter 7)**
- Sites that had other functions prior to selection and already had facilities could achieve higher sustainability indexes. Especially, for cases that THUs are supposed to be removed because of minimum negative economic and environmental impacts and almost immediately availability, as these sites have minimum environmental impacts. **(Chapters 7 and 8)**
- The assigned weights by different techniques had considerable impacts on choosing optimal subsets for TH localization. Therefore, to deal with the TH problem,

besides choosing the most appropriate weighting method, it is required to consider stakeholders concerns about priorities of indicators by involving all experts in this process. **(Chapters 5 and 8)**

- One of the main causes of stakeholders' dissatisfactions is the economic aspect. Therefore, these conditions should be considered for decision-makers, who use the weighting systems, to avoid wrong (mistake) analysis. **(Chapter 8)**

10.4. Future perspectives

A great advance has been made in relation with the temporary housing management from both the technology and the decision – making fields along this research. However, there are still numerous aspects to be covered in future research lines:

- Combination of MIVES and GIS techniques to filter locations for post-disaster TH. This would allow disregarding from the initial stages site locations with low satisfaction degree and, thus, to reduce the amount of data to be considered in decision-making process.
- Analyzing the suitability of conventional residential buildings based on the core-housing concept for progressing from THUs to permanent housing.
- Considering sustainability of renting units as temporary housing.
- Combination of MIVES and knapsack to consider suitable distribution of displaced population in rental units.

Assessing the sustainability of extending the serviceability of THUs, even considering different uses of the units.

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Nomenclature

THU	:	Temporary housing unit
TH	:	Temporary housing
DP	:	Displaced population
PDA	:	Post-disaster accommodation
HFIR	:	Housing Foundation of Islamic Republic of Iran
IRR	:	Iran Rial rates (Iranian currency)
Ec	:	Economic
S	:	Social
En	:	Environmental
SE	:	Shannon's entropy
W	:	Considering the weights assigned to the indicators
NW	:	Without considering the weights assigned to the indicators
TECH	:	Technology
SD	:	Severely damaged
CB	:	Collapsed building
MIN	:	Minimum
MAX	:	Maximum
TEMP	:	Temperature
A	:	Accepted
E	:	Equal
R	:	Refused
P	:	Private yard of DP´s previous housing
C	:	Camp site
T	:	Tent
U	:	Unit/THU
AAC	:	Autoclaved aerated concrete blocks
CMU	:	Concrete masonry unit
PR	:	Pressed reed
3D	:	3D sandwich panel
Rk	:	Requirement *k*
Ck	:	Criterion *k*
Ik	:	Indicator *k*
V	:	Value
I	:	Sustainability index
V_{R_k}	:	Requirement value
V_{C_k}	:	Criterion value
S_{max}	:	Maximum satisfaction
S_{min}	:	Minimum satisfaction
DCv	:	Decrease concavely
DCx	:	Decrease convexly

ICx	:	Increase convexly
DCv	:	Decrease concavely
DS	:	Decrease S-shape
Xmax	:	Maximum value indicator
Xmin	:	Minimum value indicator
pts.	:	Points
pop.	:	Population
min.	:	Minute(s)
pers.	:	Person(s)
N Hosp.	:	Number of hospital(s)
N Sch.	:	Number of school(s)
N P.S.	:	Number of police station(s)
N F.S.	:	Number of fire station(s)